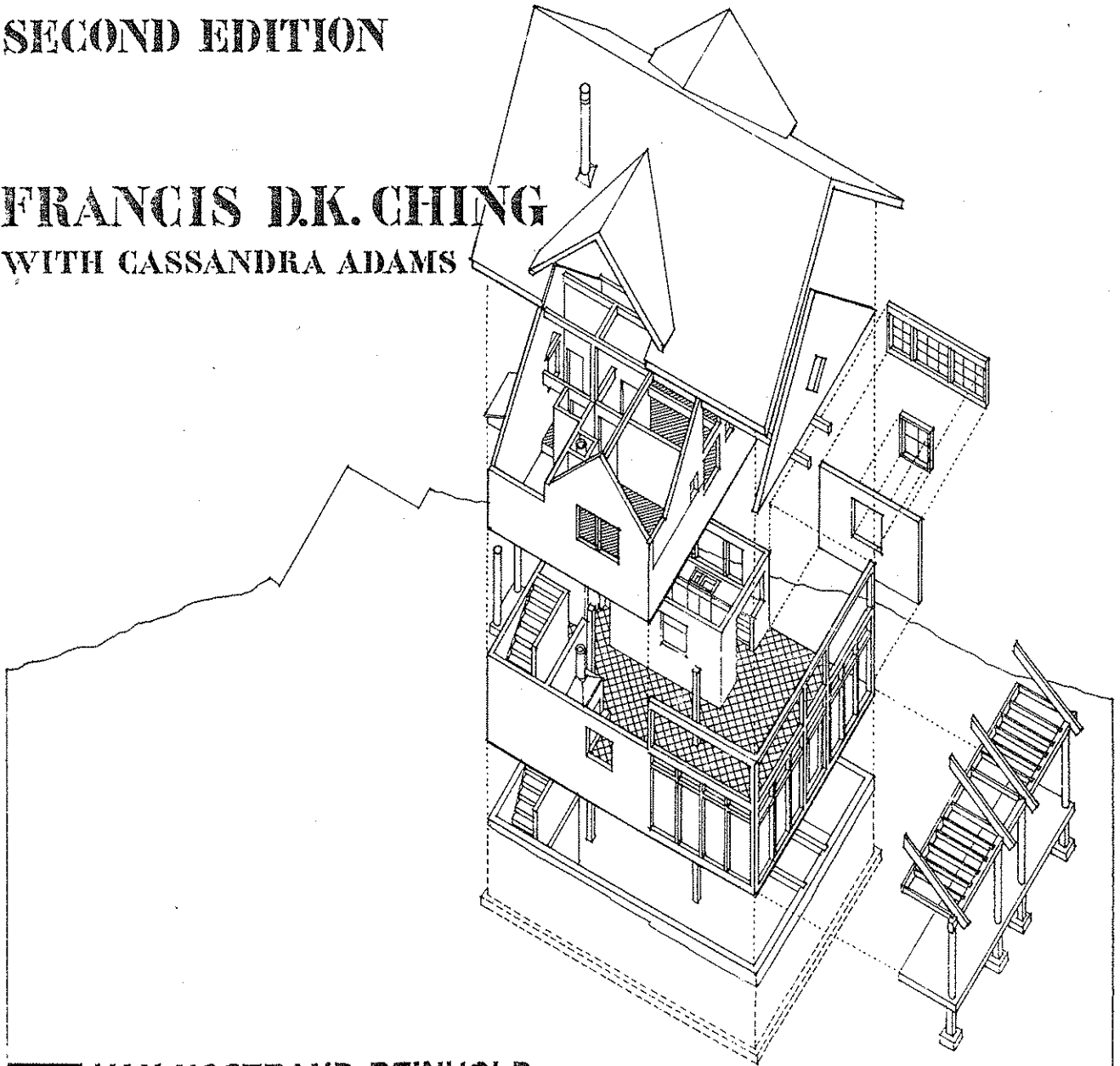


BUILDING CONSTRUCTION ILLUSTRATED

SECOND EDITION

FRANCIS D.K. CHING
WITH CASSANDRA ADAMS



VAN NOSTRAND REINHOLD

New York

Copyright © 1991 by Van Nostrand Reinhold

Library of Congress Catalog Card Number 90-25064

ISBN 0-442-23498-8 (pbk.)

ISBN 0-442-00895-3 (hard)

All rights reserved. No part of this work covered by the copyright hereon may be reproduced or used in any form or by any means — graphic, electronic, or mechanical, including photocopying, recording, taping, or information storage and retrieval systems — without written permission of the publisher.

Manufactured in the United States of America

Published by Van Nostrand Reinhold
115 Fifth Avenue
New York, New York 10003

Chapman and Hall
2-6 Boundary Row
London, SE1 8HN

Thomas Nelson Australia
102 Dodds Street
South Melbourne 3205
Victoria, Australia

Nelson Canada
1120 Birchmount Road
Scarborough, Ontario M1K 5G4, Canada

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2

Library of Congress Cataloging-in-Publication Data

Ching, Francis D.K., 1943 -

Building construction illustrated / Francis D.K. Ching;
with Cassandra Adams. — 2nd ed.

p. cm.

Includes bibliographical references and index.

ISBN 0-442-23498-8 (pbk.)

ISBN 0-442-00895-3 (hard)

1. Building. 2. House construction. I. Adams, Cassandra.

II. Title.

TH146.C52 1991

G90 - dc 20

PREFACE

The original edition of this illustrated guide to building construction introduced the student of architecture and interested lay people to the basic principles of how buildings are built. It provided an overview of the major systems of a building, how each is constructed, and how each is influenced by its relationship to other systems. While this second edition retains this perspective, it updates information where appropriate, and includes coverage of basic structural steel, reinforced concrete, and curtain wall systems. It presents as clearly as possible the material and structural choices available to the designer, and how these choices affect a building's form and dimensions, and its relationship to its site. Since this visual imagery is implicitly a very important element in the presentation of the material, information in this second edition continues to be conveyed primarily through graphic illustrations.

This handbook is organized according to a building's major components and systems. It begins with a look at the building site and the factors that influence a building's location, organization, and orientation. Following this is a description of a building's major systems, how they relate to each other, and the structural forces a building must be designed and constructed to resist. Each succeeding chapter then describes a major building system according to type of building material, structural geometry, and how each component interfaces with adjoining systems. The last chapter and the appendix provide reference information on building materials and space planning. The bibliography lists sources which, if one is interested in pursuing a subject further, can provide more in-depth information.

It would be nearly impossible to cover all building materials and construction techniques, but the information presented here should be applicable to most residential and light construction situations encountered today. Construction techniques continue to change with the development of new building materials, products, and standards. What does not change are the fundamental principles which underlie the design and construction of a building. This illustrated guide focuses on these principles, which should provide a useful context for the application of new information in the preliminary planning and design of a building.

Each building element, component, or system is described in terms of its end use. The specific form, quality, capability, and availability of an element or component will vary with manufacturer and locale. It is therefore important to always follow the manufacturer's recommendations in the use of a material and to pay careful attention to the building code requirements in effect for a building's use and location. It is the user's responsibility to judge the appropriateness of the information contained in this book and how it is to be used. Seek the expert advice of a professional when needed. On the following page is an outline of the basic considerations which may be applied to almost any building material, component, or system to measure its appropriateness for a given design or construction situation.

The information in this book can be categorized according to the following factors:

- MATERIALS**
- Structural properties (see STRUCTURE below)
 - Physical properties of
 - Weight and density
 - Thermal expansion and conductivity
 - Permeability to water vapor
 - Fire resistance
 - Acoustical value
 - Form, dimensional characteristics, and visual properties
 - Durability - resistance to
 - Physical wear and abrasion
 - The effects of sun, wind, and rain
 - Corrosion caused by moisture or chemical action
 - Finish and maintenance requirements
 - Method of manufacture and supply
- STRUCTURE**
- Form and geometry: linear, planar, or volumetric
 - Forces to be resolved
 - Compressive, tensile, shear
 - Vertical (downward or uplift), lateral, or angled
 - Concentrated or uniformly distributed
 - Static dead and live loads; dynamic wind and seismic forces
 - Strength, stiffness, and elasticity of the materials used
 - Types of connections required
 - Pinned, rigid, or roller joints
 - Butt, lap, or interlocking connections
 - Foundation, bearing, and support requirements
 - Structural requirements for cantilevers, suspended construction, and openings
- CONSTRUCTION**
- Number and sizes of the pieces to be assembled
 - Modular constraints, if any
 - Method of fastening required
 - Mechanical (nails, screws, bolts, rivets, clips)
 - Welded
 - Adhesive
 - Equipment, tools, and workmanship required
 - Place of assembly: on-site or at the factory
 - Standardization of parts and prefabrication where advantageous
 - Work coordination, erection time, and labor requirements
- THE CONSTRUCTION ASSEMBLY**
- Control of the flow of
 - Heat
 - Thermal conductivity and reflectivity
 - Thermal expansion characteristics
 - Air
 - Ventilation and infiltration
 - Water
 - Permeability to water vapor
 - Waterproofing requirements
 - Ice and snow protection
 - Fire resistance and acoustical rating
 - Construction thickness or depth
 - Accommodation of mechanical and electrical equipment and systems
- GENERAL FACTORS**
- Fitness for use and purpose
 - Safety, comfort, and health requirements
 - Compliance with applicable building codes
 - Initial and life costs

CONTENTS

PREFACE

- 1 THE BUILDING SITE
- 2 THE BUILDING
- 3 FOUNDATION SYSTEMS
- 4 FLOOR SYSTEMS
- 5 WALL SYSTEMS
- 6 ROOF SYSTEMS
- 7 DOORS & WINDOWS
- 8 MOISTURE & THERMAL PROTECTION
- 9 SPECIAL CONSTRUCTION
- 10 FINISH WORK
- 11 MECHANICAL & ELECTRICAL SYSTEMS
- 12 NOTES ON MATERIALS
- A APPENDIX

BIBLIOGRAPHY

INDEX

THE BUILDING SITE

In planning the design and construction of a building, we should carefully consider the environmental forces which the physical context for the building—its site—presents. A site's geographic location, topography, plant materials, climate, and orientation to the sun and prevailing winds all influence decisions at a very early stage in the design process. These environmental forces can help shape a building's form, articulate its enclosure, establish its relationship to the ground plane, and suggest the way its interior spaces are laid out.

In addition to environmental forces, there may exist the regulatory forces of zoning ordinances. These regulations may prescribe acceptable uses for a building site as well as limit the size and shape of the building mass and where it may be located on the site.

Included in this chapter are site improvements which modify a building site for access and use, define the boundaries of exterior spaces, and relate the building to the surrounding ground plane. These construction details typically are closely related to the design of the building itself and can be seen to be logical extensions of the way the building is constructed.

1.2 THE BUILDING SITE: ENVIRONMENTAL FACTORS

GEOGRAPHIC FACTORS: SOIL

The soil type affects:

- the type and size of a building's foundation system
- the drainage of ground and surface water
- the types of plant material able to grow on a site

TOPOGRAPHY

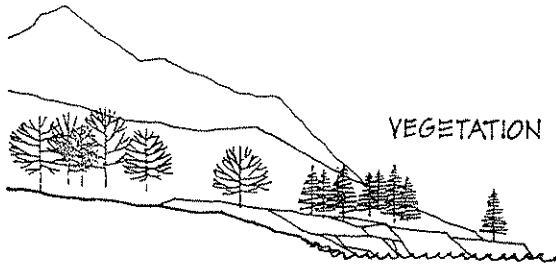
Land forms and ground slopes affect:

- the building foundation type
- the building form and its relationship to the ground plane
- site drainage
- the site's micro-climate: wind, temperature, solar radiation

VEGETATION

The types and locations of plant materials affect:

- the site's micro-climate: solar radiation, wind, humidity, air temperature and purity
- the definition or visual screening of exterior spaces
- the absorption or dispersion of sound



CLIMATIC FACTORS:

The following climatic factors affect a building's form, orientation, and construction.

The sun is the source of:

- solar radiation (heat gain)
- natural light

The prevalence, direction, and velocity of wind affect:

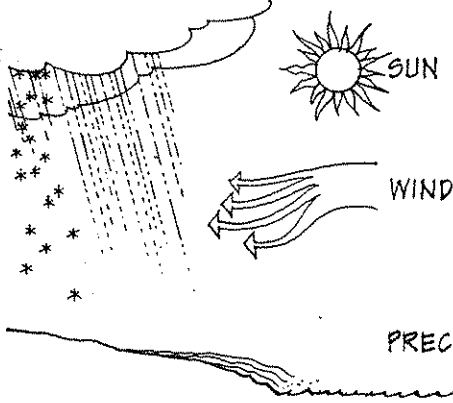
- air infiltration into a building (potential heat loss)
- the ventilation of interior spaces and outdoor courts
- the lateral load on a structure

The prevalence and amount of precipitation affect:

- the roof form, its construction, and the resulting gravity load on the structure
- the presence and drainage of water on a site
- the choice of building materials

TEMPERATURE

Air temperature and thermal comfort are affected by all of the above climatic factors.



SENSORY FACTORS:

VIEWS

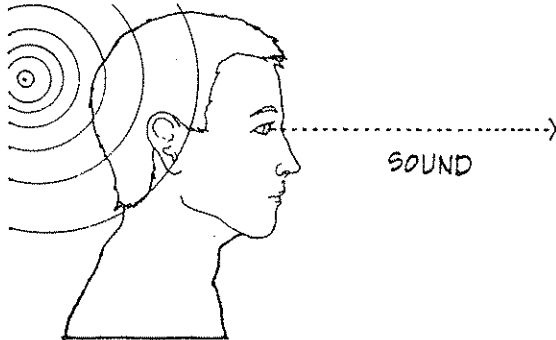
The consideration of desirable and undesirable views will help determine:

- the building form and orientation
- the building's fenestration (door and window openings)
- the plant materials used in landscaping the site

SOUND

The level, quality, and source of sounds affect:

- the distribution and orientation of the building mass
- the choice of building materials and their assembly
- the sound control methods used



REGULATORY FACTORS

Zoning ordinances govern the use and bulk of buildings and structures within a municipality or land use district. These ordinances typically regulate:

- the types of activities which may occur on a given piece of land
- how much of the land can be covered by a building
- how far a building must be set back from each of the property lines
- how tall the building structure can be
- the total floor area that can be constructed

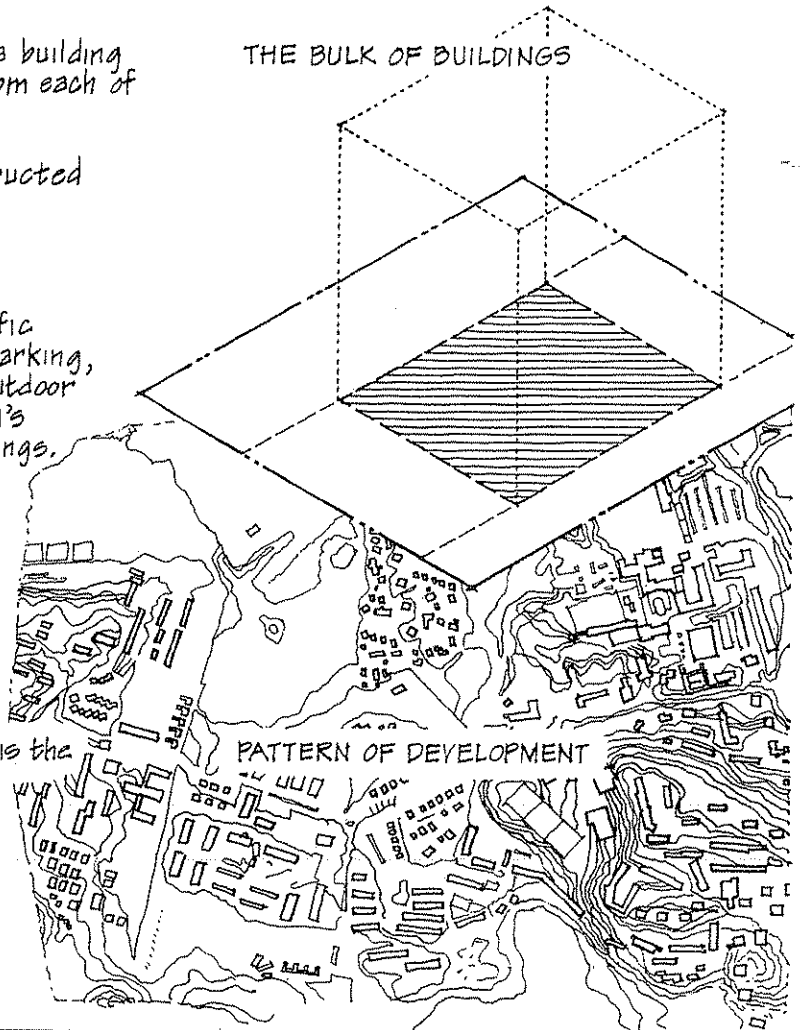
A zoning ordinance may also contain specific requirements for access and off-street parking, accessory structures such as fences and outdoor decks, and the projections from a building's facades such as balconies and roof overhangs.

The cumulative effect of zoning ordinances is the management of the density and pattern of development within various land use zones.

ZONING ORDINANCES REGULATE

LAND USE

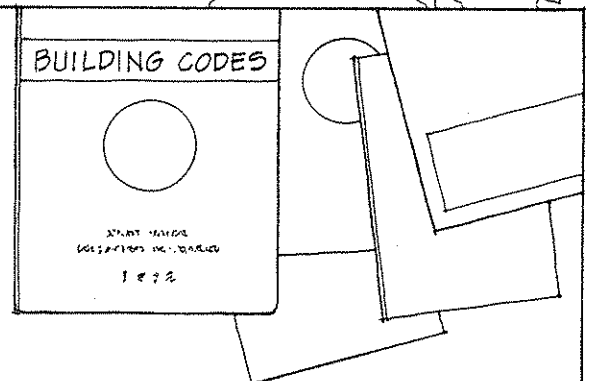
THE BULK OF BUILDINGS



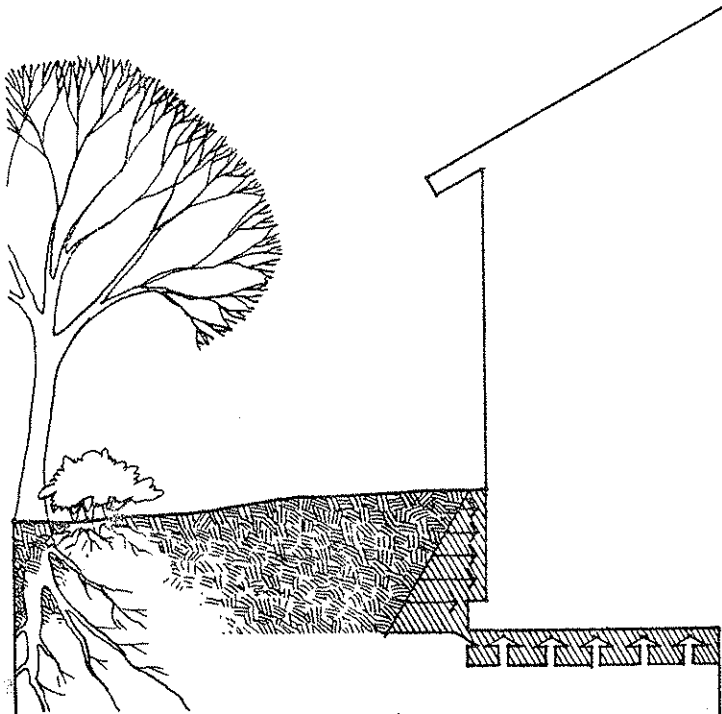
Other regulatory instruments exist which affect the way buildings are sited and constructed. These statutes – commonly referred to as the building code – establish the relationship between:

- the type of occupancy a building houses
- the fire-resistance rating of its structure and construction
- the allowable height and floor areas of the building, and its separation from neighboring structures

See Appendix for more information on building codes.



1.4 SOILS



To support plant life, a soil must:

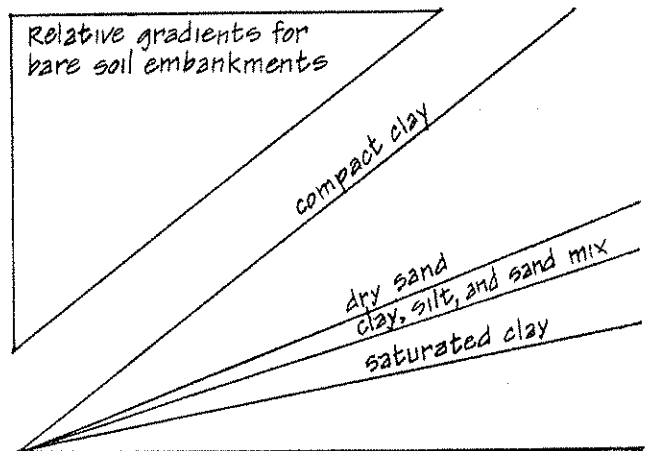
- be capable of absorbing moisture
- supply the appropriate plant nutrients
- be capable of aeration
- be free of concentrated salts

Practically all buildings rely on soil for their ultimate support. The integrity of a building structure therefore depends ultimately on the type of soil underlying the foundation and the soil's strength under loading.

There are two broad classes of soils—coarse-grained and fine-grained soils. Coarse-grained soils include gravels and sands which consist of relatively large particles. The individual particles of fine-grained soils are much smaller and often cannot be seen by the eye. The soil underlying a building site may actually consist of superimposed layers, each of which contains a mix of soil types.

A soil's stability and strength under loading depends largely on its resistance to shear, which is a function of both its internal friction and its cohesiveness. Coarse-grained soils with a relatively low percentage of void spaces are more stable as a foundation material than silt or clay. Clay soils, in particular, tend to be unstable since they shrink and swell considerably with changes in moisture content.

SOIL CLASSIFICATION		Sieve Size	Particle Size (mm)
Coarse-grained soils	Cobbles	> 3"	> 60.
	Coarse gravel	> 3/4"	> 19.
	Fine gravel	> No 4	> 5.5
	Coarse sand	> No 10	> 2.0
	Medium sand	> No 40	> 0.6
	Fine sand	> No 200	> 0.08
Fine-grained soils	Fines (silt and clay)	< No 200	< 0.08



On sloping sites, and during the excavation of a flat site, a soil's potential for lateral displacement should be considered. The natural angle of repose for dry, granular soils tend to be shallower than for more cohesive soils like compacted clay.

SOIL MECHANICS

The usual measure of a soil's strength is its bearing capacity in pounds per square foot. A foundation system must distribute a building's loads in such a way that the resultant unit load on the soil does not exceed the soil's bearing capacity and is uniform under all portions of the structure. While high bearing capacity soils present few problems, low bearing capacity soils may dictate the type of foundation and load distribution pattern for a building, which in turn affects the building's form. Unstable soils usually render a site unbuildable unless an elaborately engineered and expensive foundation system is put in place.

The table below outlines, for reference only, the relative strengths of various soil types. Refer to the local building code for the allowable bearing capacities of general classes of soils. Most soils are in fact a combination of different soil types. The stratification, composition, and density of the soil bed, variations in particle size, and the presence or absence of water are all important factors in determining a soil's bearing capacity. When designing a sizable structure or when there are unusual load conditions, it is advisable to have a soils engineer test borings taken from the actual site.

- In cold weather, the freezing and subsequent thawing of soil can cause ground heaving, which places stress on a building's foundation and structure. The extent of this frost action depends on the site's geographic region and the soil type. Fine-grained soils are more susceptible to frost action than coarse-grained soils. In any case, a building's footings should always be placed well below the site's frost line.

- A soil's permeability should also be taken into account to ensure that surface and ground water can be properly channeled away from the building structure. Proper drainage is required to avoid deterioration of a soil's bearing capacity and to minimize the possibility of water leaking into a building's interior. Coarse-grained soils are more permeable and drain better than fine-grained soils. Fine silts and clays also have greater capillarity which can cause water to migrate upward above a site's water table.

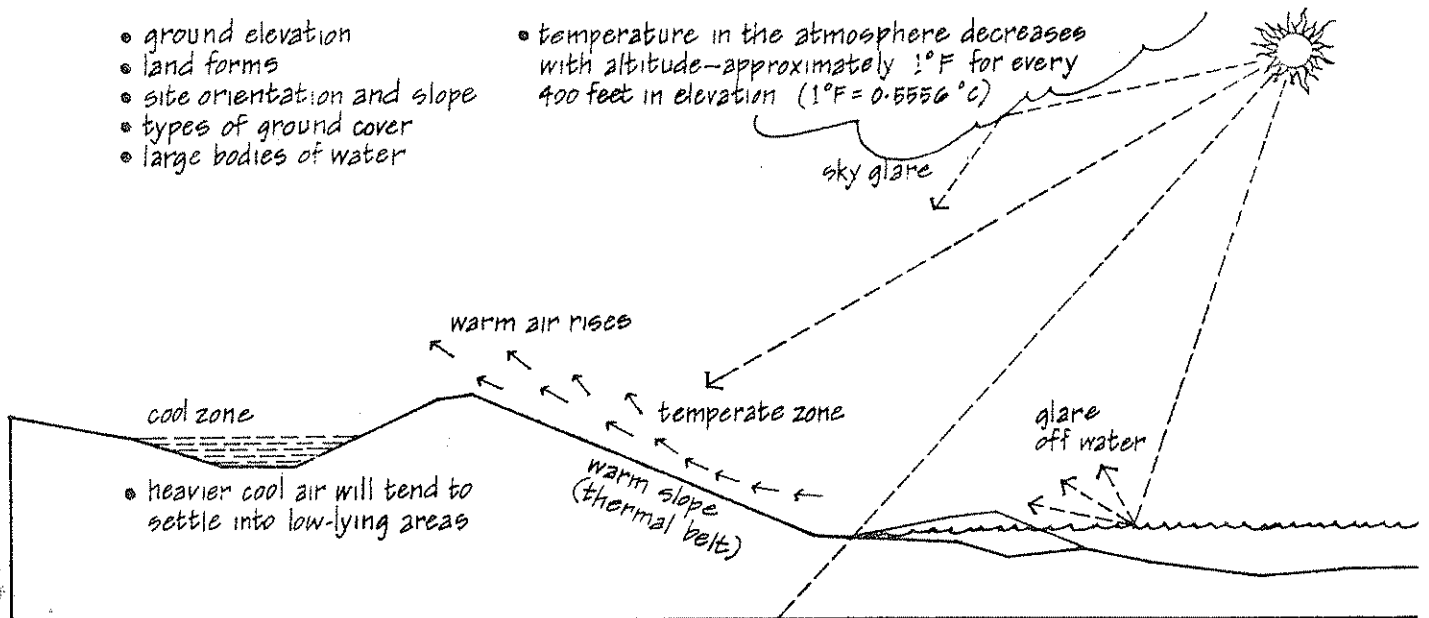
SOIL TYPE	Presumed Bearing Capacity (tons/ft. ²) : (kg/m ²)		Susceptibility to Frost Action	Drainage (permeability)
Compact, partially cemented gravels; well-graded with little or no fines	10	97 650	none	excellent
Compact gravel; gravel and sand mixtures	6	58 590	none	excellent
Coarse, compact sand; loose gravel; hard, dry clay	4	39 060	slight	fair to good
Coarse, loose sand and gravel mixtures; fine, compact sand	3	29 295	slight	fair to good
Fine, loose sand; dry, stiff clay	2	19 530	high	fair to poor
Soft clay; soft, broken shale	1.5	14 648	high	poor
Organic soils	Unsuitable as a foundation material; can be highly unstable due to bacterial decomposition and changes in moisture content			

1.6 TOPOGRAPHY AND CLIMATE

All of the following factors affect variations in local climate:

- ground elevation
- land forms
- site orientation and slope
- types of ground cover
- large bodies of water

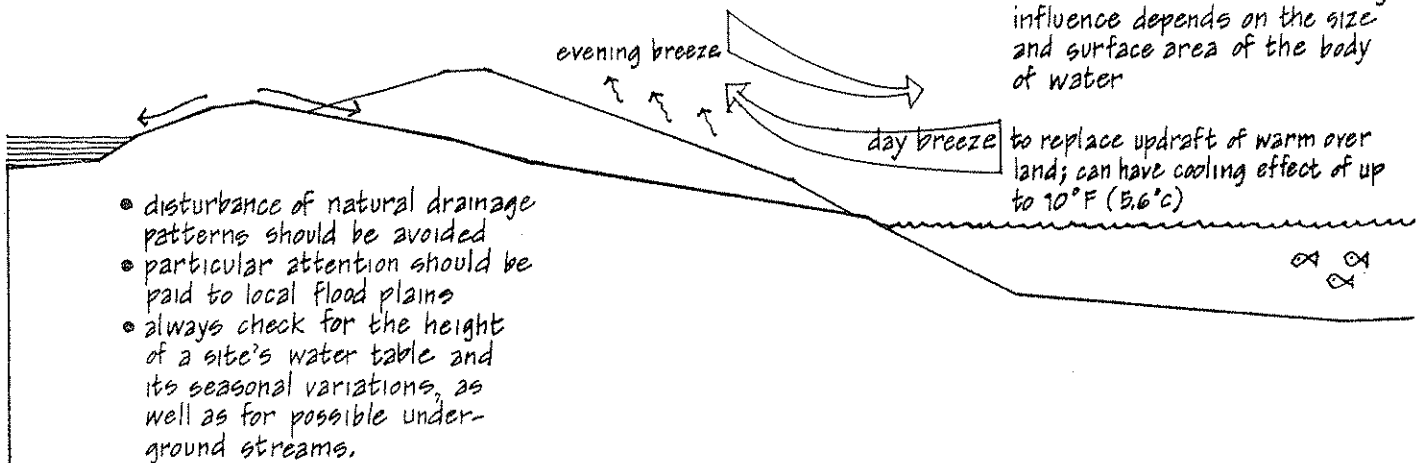
- temperature in the atmosphere decreases with altitude—approximately 1°F for every 400 feet in elevation ($1^{\circ}\text{F} = 0.5556^{\circ}\text{C}$)



- grass and other ground covers tend to lower temperatures by absorbing insolation and encouraging cooling by evaporation

- hard surfaces tend to elevate temperatures; light-colored surfaces reflect solar radiation while dark surfaces absorb and retain insolation

- large bodies of water act as heat reservoirs and tend to moderate temperature variations
- they are generally warmer than land in winter and cooler in summer
- they are generally cooler than land during the day and warmer at night, generating offshore breezes
- the extent of this moderating influence depends on the size and surface area of the body of water

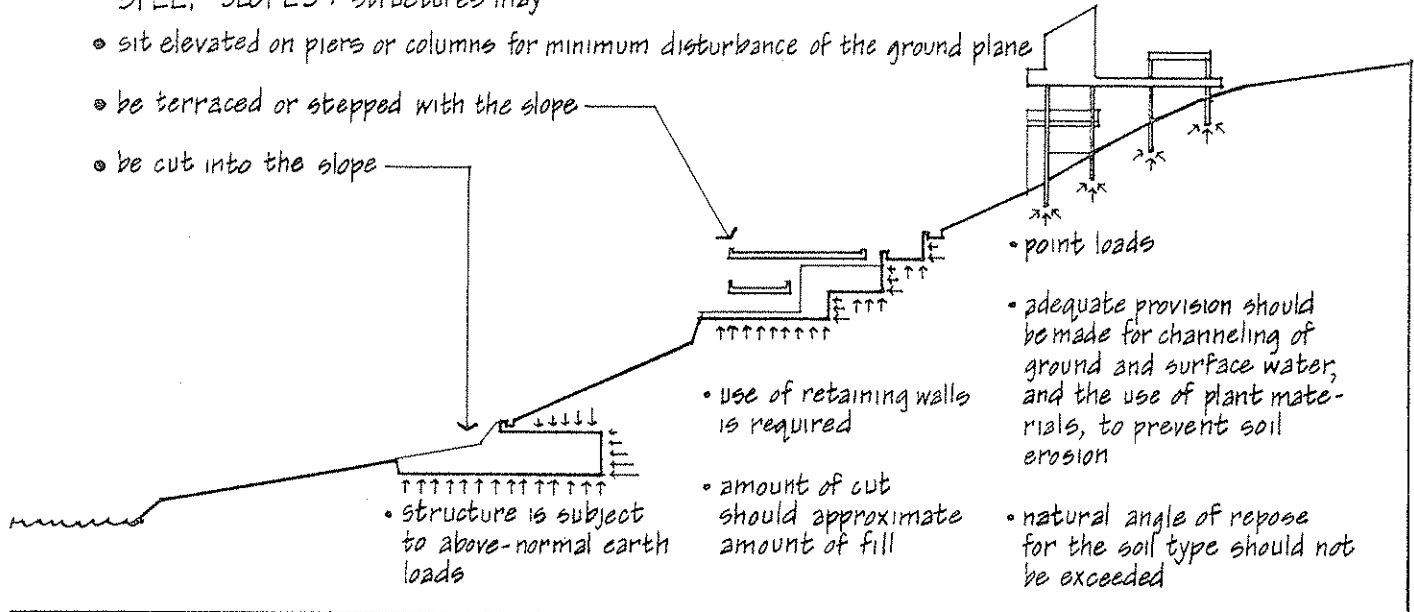


TOPOGRAPHY AND BUILDING FORM

1.7

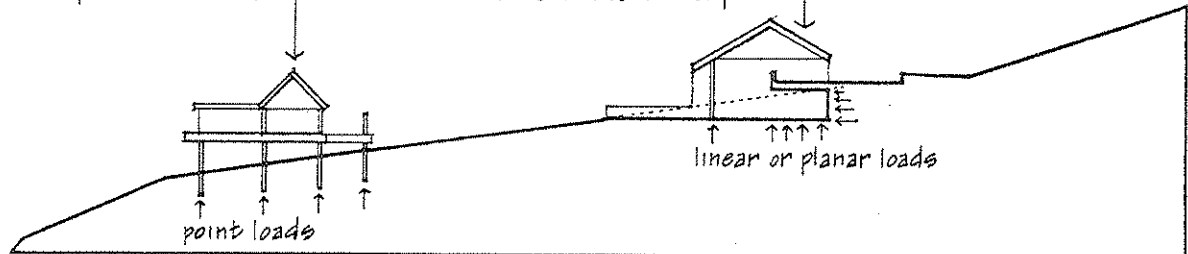
STEEP SLOPES: structures may

- sit elevated on piers or columns for minimum disturbance of the ground plane
- be terraced or stepped with the slope
- be cut into the slope



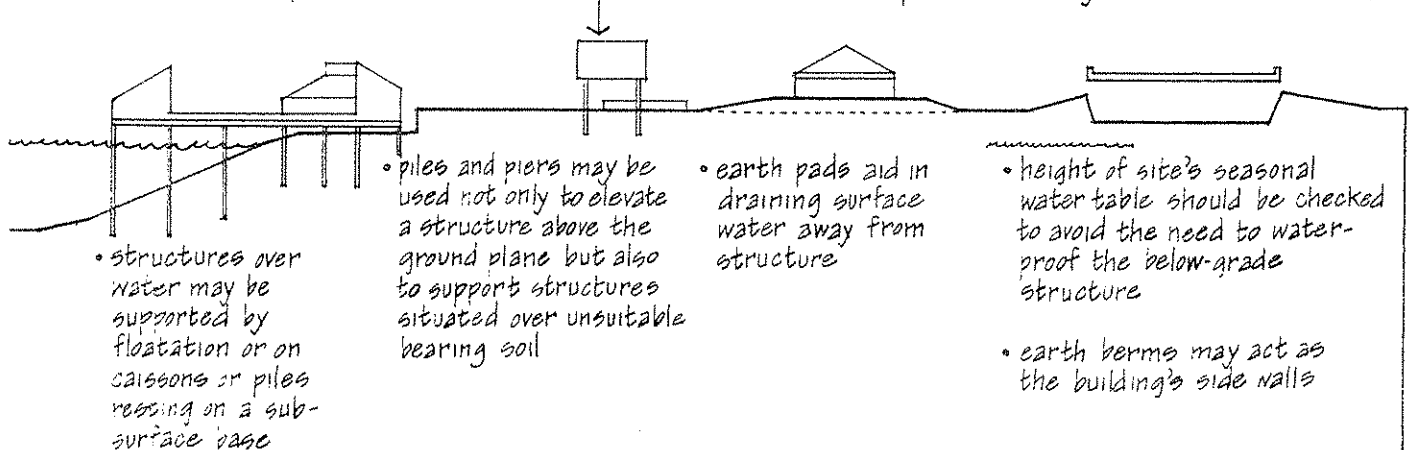
MODERATE SLOPES: structures may

- be elevated on piers or columns
- be cut into the slope



FLAT SLOPES: structures may

- be elevated on piers or columns
- sit on a raised pad
- be dug into earth and bermed



1.8 PLANT MATERIALS

Factors to consider in the selection and use of trees in landscaping include:

- form, density, texture, and color of the foliage
- potential growth height and spread
- speed or rate of growth
- size and depth of the root structure
- requirements for soil, water, sunlight, air and temperature

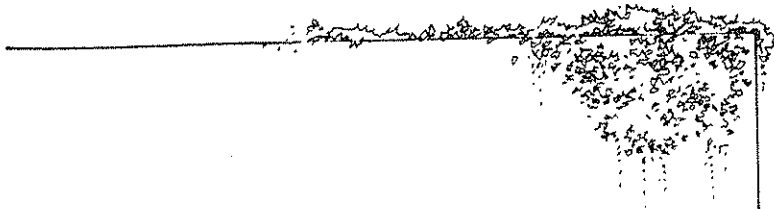
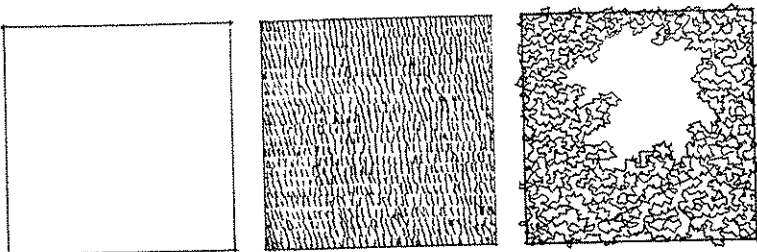
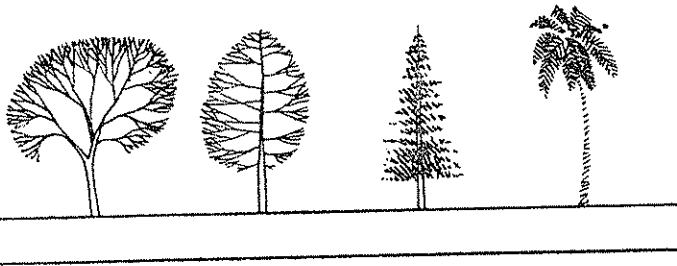
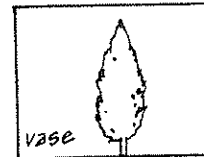
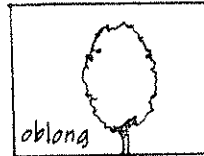
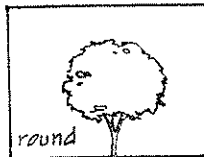
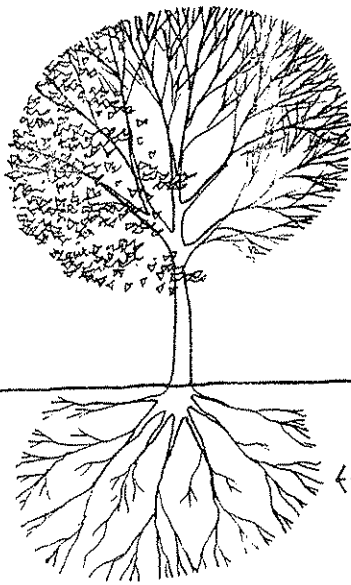
- the root systems of trees planted too close to a building may disturb the foundation system
- similarly, a tree's root structure may interfere with underground utility lines

- the manner in which trees and other plant life adapt their forms to climate provides clues to the ways buildings might do the same

Grass and other ground covers:

- can reduce air temperatures by absorbing insolation and encouraging cooling by evaporation
- aid in stabilizing soil and preventing erosion
- increase a soil's permeability to air and water

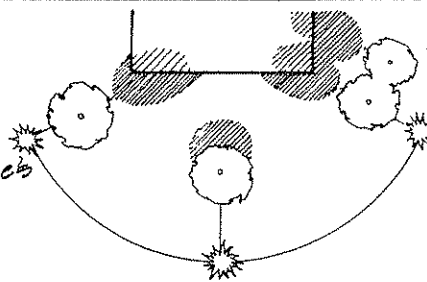
- Vines can reduce the heat transmission through a sunlit wall by providing shade and cooling the immediate environment by evaporation



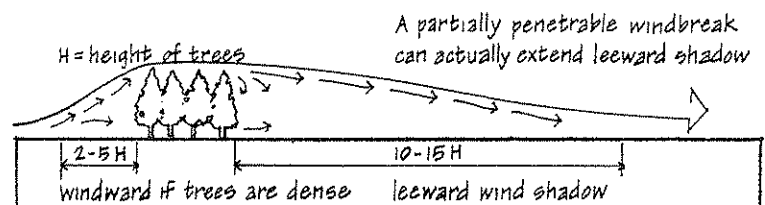
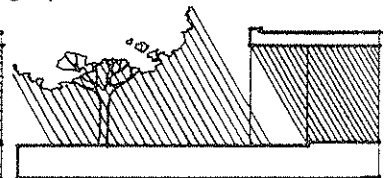
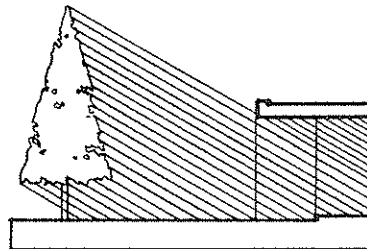
TREES AND ENVIRONMENT

Trees affect the immediate environment of a building by:

- providing shade
 - the amount of shade depends on the trees
 - orientation to the sun
 - proximity to the building
 - shape, spread, and height
 - density and branch structure
 - deciduous trees provide shade and glare protection during the summer, and let solar radiation (as well as glare) through during the winter
 - evergreens provide shade throughout the year and help reduce snow glare during the winter
- reducing sky, ground, and snow glare
- providing wind protection
 - foliage reduces wind-blown dust
 - evergreens can form effective windbreaks during the winter and reduce a building's heat losses
- intercepting precipitation and filtering the air
- aiding in soil stabilization, increasing its permeability to water and air, and preventing erosion

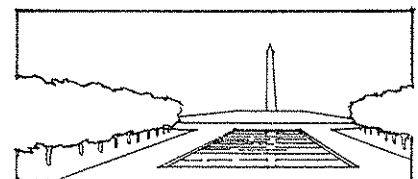
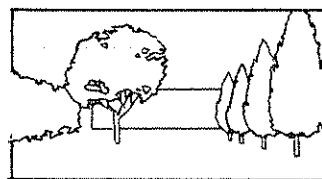


- trees shade a building most effectively from the southeast and the southwest when the morning and late afternoon sun has a low altitude and casts long shadows
- south-facing overhangs provide more efficient shading during the midday period when the sun is high and casts short shadows



- the approximate area of protection indicated above varies with the height and density of the trees, and with wind velocity
- the protection provided is primarily a reduction in wind velocity producing an area of relative calm

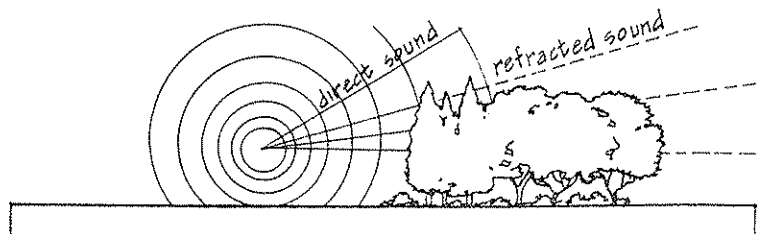
- defining space and directing views



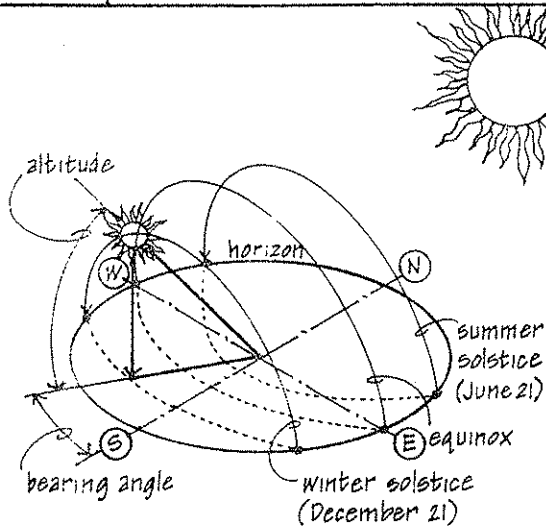
- providing visual screening and privacy



- attenuating airborne sounds



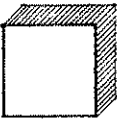
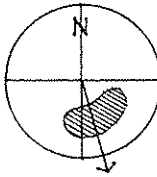
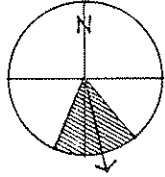
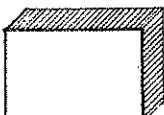
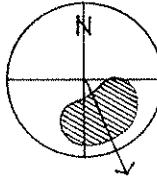
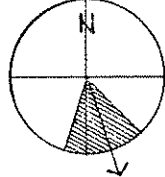
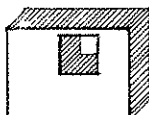
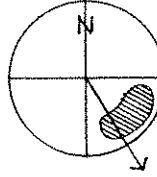
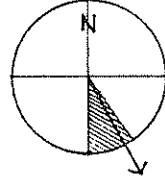
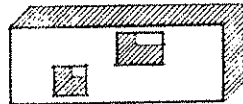
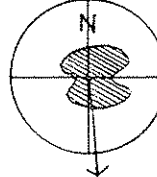
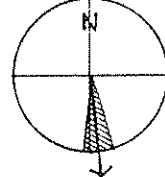
1.10 THE SUN



A building's location, orientation, and form should take advantage of the sun's thermal, hygienic, and psychological benefits. The sun's radiation, however, may not always be beneficial, depending on the building site's climate. In determining a building's form and orientation, the objective should be to maintain a balance between overheated periods when solar radiation is beneficial and overheated periods when radiation should be avoided. The long face of a building should normally face south if possible. East and west exposures are generally warmer in summer and cooler in winter than southern exposures.

The sun's path through the sky varies with the seasons and a site's latitude. Its altitude and bearing angle range should be determined before calculating solar heat gain and shading requirements for a specific site.

The table below pertains primarily to isolated buildings. The information presented should be considered along with other contextual and programmatic requirements.

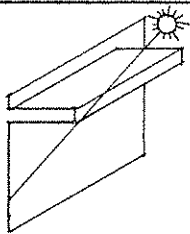
OPTIMUM SHAPE	LOCATION	GENERAL OBJECTIVES	ORIENTATION
 low temperatures encourage minimizing of a building's surface area		COOL REGIONS <ul style="list-style-type: none"> • increase solar radiation absorption • reduce radiation, conduction, and evaporation heat loss • provide wind protection 	
 temperate climate allows for elongation along the east-west axis		TEMPERATE REGIONS <ul style="list-style-type: none"> • balance solar heat gain with shade protection on a seasonal basis • encourage air movement in hot weather; protect from wind in cold weather 	
 closed forms; building mass enclosing cool air ponds desirable		HOT-ARID REGIONS <ul style="list-style-type: none"> • reduce solar radiation and conduction heat gain • promote cooling by evaporation using water and plantings • provide shade 	
 form may be freely elongated along east-west axis to minimize east and west exposure		HOT-HUMID REGIONS <ul style="list-style-type: none"> • reduce solar heat gain • utilize wind to promote cooling by evaporation • provide shade 	

SOLAR SHADING DEVICES

Shading devices shield a building's exterior surfaces and interior spaces from solar radiation. Their effectiveness depends on their form and orientation relative to the sun's angles. Exterior shading devices are more efficient than those located within a building's spaces since they intercept the sun's radiation before it can reach the building's surfaces.

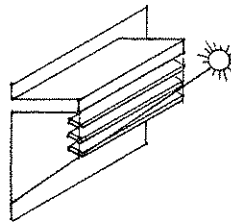
Below are illustrated basic types of solar shading devices. Their orientation, form, materials, and construction may vary to suit specific situations. Their visual qualities (pattern, texture, rhythm, and the shadows they cast) contribute much to a building's appearance.

Since a building's exterior walls and roof are its primary sheltering elements against solar radiation, the materials used in their construction should be considered in terms of their reflectivity and thermal conductivity. A material's reflectivity depends on its color and texture. Light colors and shiny surfaces tend to reflect more radiation than dark, textured ones. Effective insulating materials usually incorporate some form of captured dead air space. Massive materials such as masonry absorb and store heat for a period of time, thus delaying heat transmission.



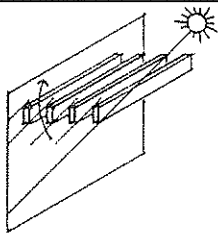
HORIZONTAL OVERHANGS

- most effective when they have southern orientations



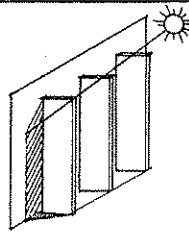
HUNG LOUVERS

- louvers hung from a solid overhang provide protection for low sun angles
- may interfere with view



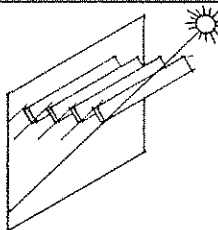
HORIZONTAL LOUVERS

- horizontal louvers parallel to wall permit air circulation near the wall and reduces conduction heat gain
- may be operable to adapt to sun's angle



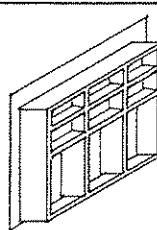
VERTICAL LOUVERS

- most effective for eastern or western exposures
- may be operable to adapt to sun's angle
- separation from wall reduces conduction heat gain



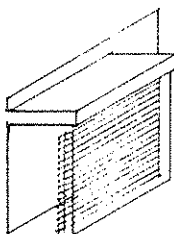
HORIZONTAL LOUVERS

- slanted louvers provide more protection than those parallel to wall
- angle varies according to sun's altitude range



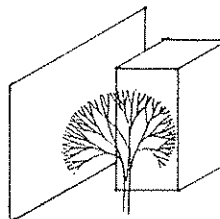
EGGCRATES

- eggcrates combine the characteristics of horizontal and vertical louvers and have a high shading ratio
- efficient in hot climates



BLINDS • GLASS

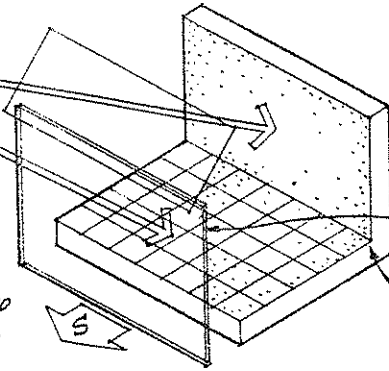
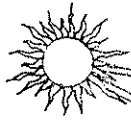
- blinds and drapes can provide up to 50% reduction in radiation depending on reflectivity
- heat-absorbing glass can absorb up to 40% of the radiation reaching its surface



TREES • ADJACENT BUILDINGS

- trees and adjacent structures may provide shade depending on their proximity, height, and orientation

1.12 PASSIVE SOLAR DESIGN



- double-glazing and insulation required to minimize nighttime heat loss
- approximately 0.20-0.30 square feet of glazing required for each square foot of floor area
- glazing material should be resistant to degradation caused by sun's ultraviolet rays

concrete: 12"-18"
brick: 10"-14"
adobe: 8"-12"
water: 6" or more

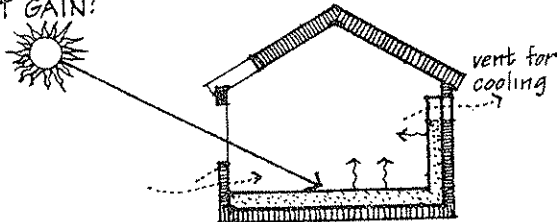
Passive solar design refers to using the sun's energy to heat a building's interior spaces through nonmechanical means. Passive solar systems rely on the natural heat transfer processes of conduction, convection, and radiation for the collection, storage, distribution, and control of solar energy. There are two basic elements in every passive solar system:

- ① south-facing glass or transparent plastic for solar collection
- ② thermal mass for heat collection, storage, and distribution, oriented to receive maximum solar exposure

The thermal mass allows the sun's heat to be absorbed and retained until it is needed, and also helps to reduce internal temperature fluctuations.

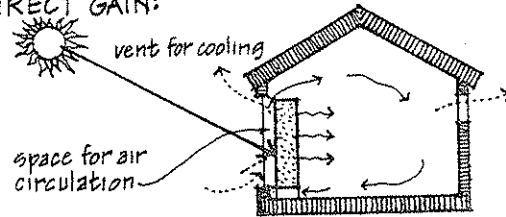
Based on the relationship between the sun, the interior space, and the heat collection system, there are three ways in which passive solar heating can be accomplished: direct gain, indirect gain, and isolated gain.

DIRECT GAIN:



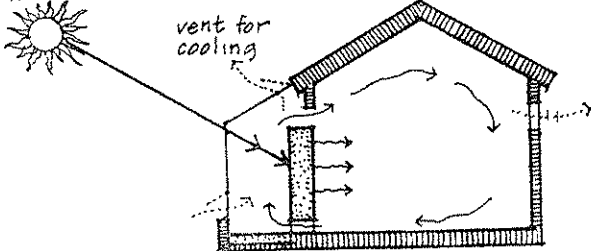
Direct gain systems collect heat directly within an interior space. The surface area of the storage mass, which is incorporated into the space, should be $\frac{1}{2}$ to $\frac{2}{3}$ of the total surface area of the space. Operable openings are used for cooling by ventilation.

INDIRECT GAIN:



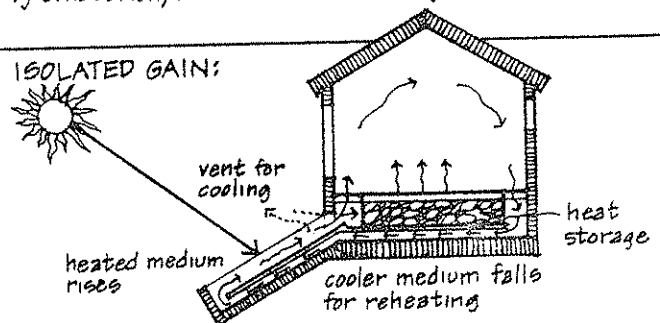
Indirect gain systems control heat gain at the building's exterior skin. The sun's radiation first strikes the thermal wall mass which is located between the sun and the living space. Solar heat is absorbed by the thermal wall and then to the space by conduction, and to some extent by convection.

INDIRECT GAIN:



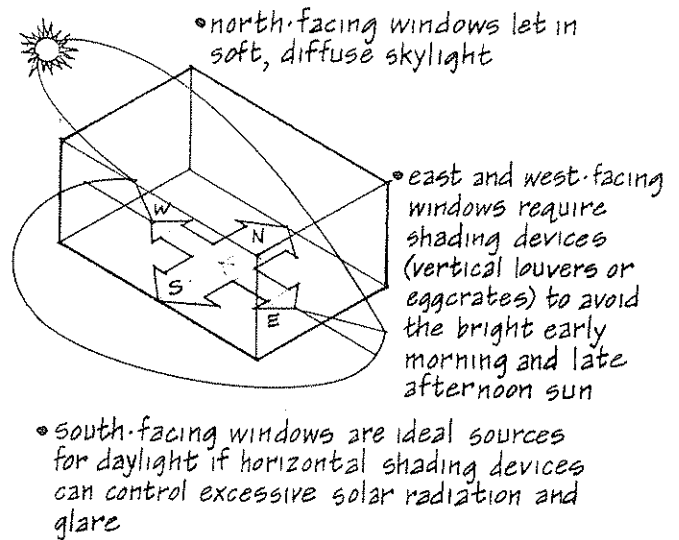
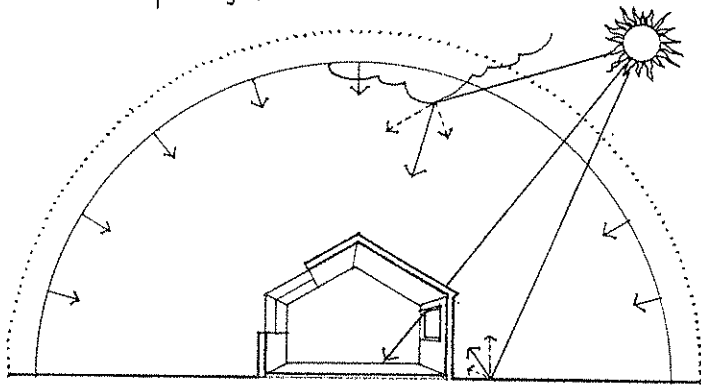
A sunroom or solarium can be introduced as a medium for heat gain. This sunspace is separated from the main living space by a thermal storage wall from which heat is drawn as needed. For cooling, the sunspace can be vented to the exterior.

ISOLATED GAIN:



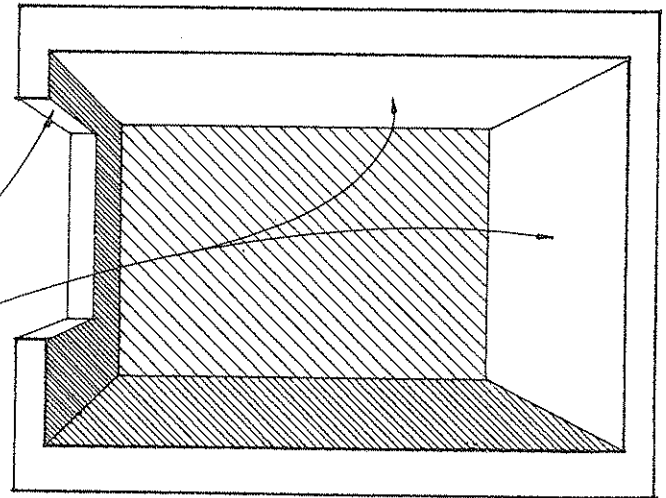
Isolated gain systems collect and store heat away from the living space. As air or water in a collector is warmed by the sun, it rises to the living space or to a thermal mass. Simultaneously, cooler air or water is pulled from the storage bottom, creating a natural convection loop.

The sun's radiation provides not only heat but also light for a building's interior spaces. This daylight has psychological benefit as well as practical utility. While intense, the sun's light will vary with the time of day, from season to season, and from place to place. It can be diffused by cloud cover, haze, and precipitation, and reflected from the ground and other surrounding surfaces. The quantity and quality of daylighting in a space are determined primarily by the size and orientation of its window openings.

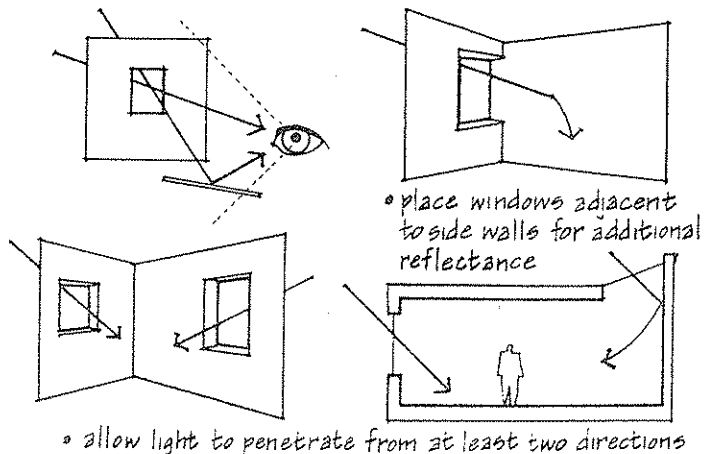


The level of illumination provided by daylight falls off as it penetrates an interior space. Generally, the larger and higher a window is, the more daylight will enter a room. A useful rule of thumb is that daylighting can be effective for task illumination up to a depth of twice the height of a window.

The ceiling and back wall of a space are more effective than the side walls or the floor in the reflection and distribution of daylight. Light-colored surfaces reflect and distribute light more efficiently but large areas of shiny surfaces can cause glare.

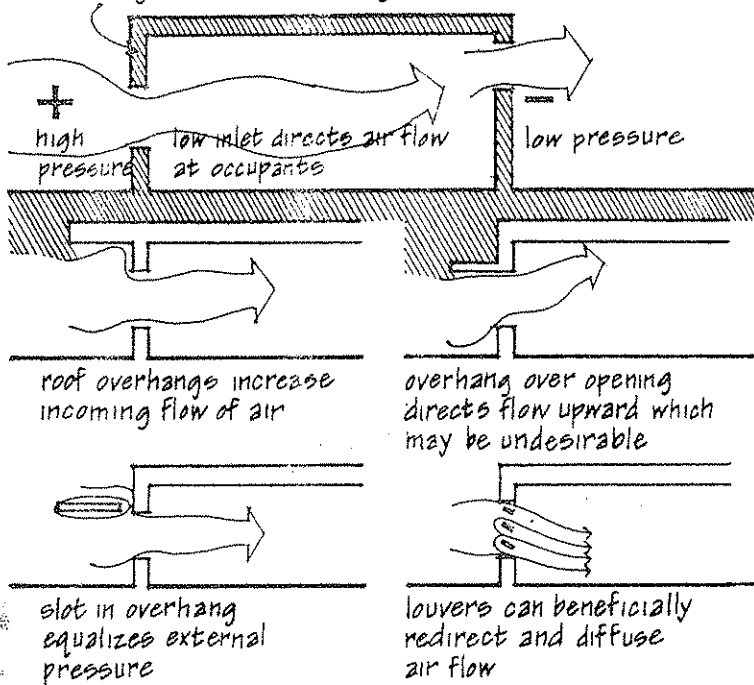


Excessive brightness ratios can lead to glare and impairment of visual performance. There are two types of glare. Direct glare is caused by the excessive contrast between light in our normal field of vision and the subject of a visual task. Indirect glare is caused by a task surface reflecting a light source into our eyes. Glare can be controlled by the use of shading devices, the proper orientation of task surfaces, and allowing daylight to enter a space from at least two directions.



1.14 WIND

a high inlet would direct air flow upward, resulting in a loss of cooling effect



Wind prevalence, velocity, temperature, and direction are important site considerations in all climatic regions. In evaluating the wind's potential effect on a building, its seasonal and daily variations should be carefully considered.

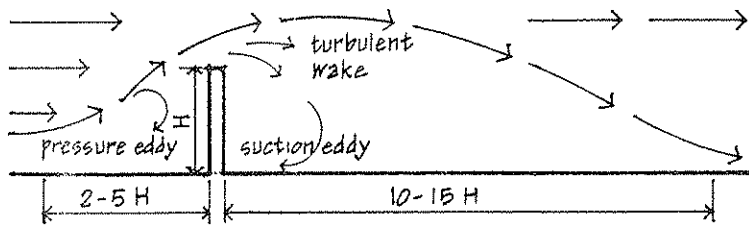
Wind-induced ventilation of interior spaces aids in the air exchange necessary for health and odor removal. In hot weather, and especially in humid climates, ventilation is beneficial for convective or evaporative cooling.

Natural ventilation in buildings is generated by differences in air pressure as well as temperature. The resulting air flow patterns are affected more by building geometry than by air speed.

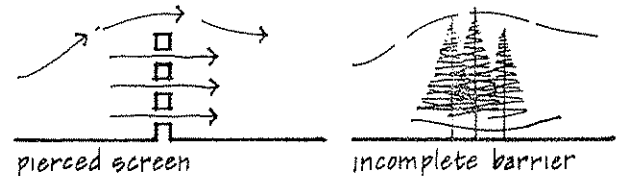
- position of outlet has little effect on air flow pattern, but should be high to let rising warm air escape
- outlet should be as large or larger than inlet for maximum air flow
- interior partitions and large furnishings may adversely alter air flow patterns

The ventilation of concealed roof and crawl spaces is required to remove moisture and control condensation. In hot weather, attic ventilation can also reduce overhead radiant heat gain.

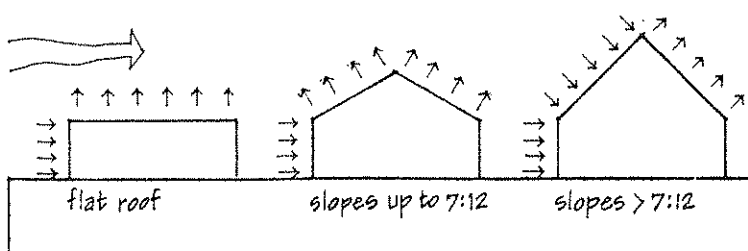
A building should be buffered against cold winds to reduce air infiltration into its interior and lower heat loss. A windbreak may be in the form of an earth beam, a garden wall, or dense trees.



Windbreaks reduce wind velocity and produce an area of relative calm on their leeward side. The extent of this wind shadow depends on a windbreak's height, density, depth, and orientation to the wind.

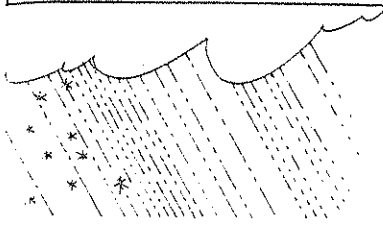


A partially penetrable windscreen creates less pressure differential, resulting in a larger wind shadow to the lee side of the screen.

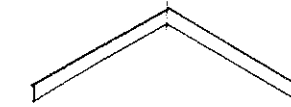


Wind creates pressure on the windward side of a building and suction on its other three sides. Wind also produces suction on flat roofs, on the leeward side of sloping roofs, and even on the windward side of roofs with a pitch less than 7:12.

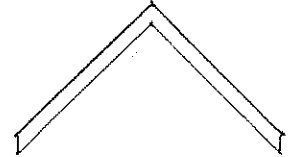
PRECIPITATION



- flat roofs require either interior roof drains or scuppers along their perimeter
- water-cooled roofs used in hot-dry climates must support above normal roof loads
- in cold climates, flat roofs are subject to heavy snow loads; layer of snow can act as additional insulation



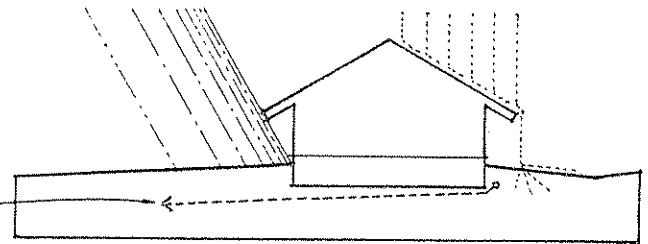
- moderately pitched roofs easily shed rain but may hold snow



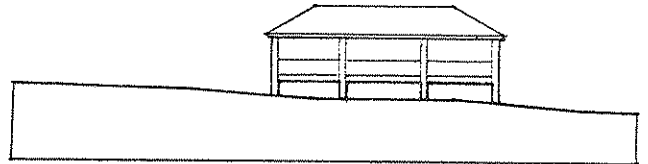
- steeply pitched roofs have fast runoff of rain water, and if the angle of the slope is greater than 60°, can also slough off snow

- overhangs protect a building's exterior walls from the weathering effects of sun and rain

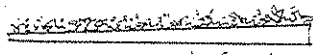
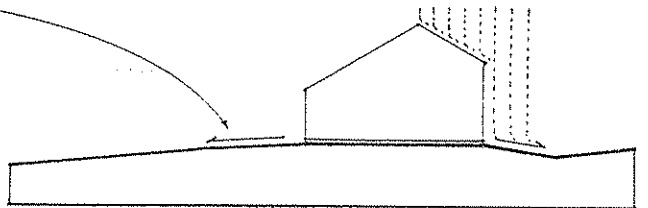
- dampproofing or waterproofing is required for below-grade spaces when ground water is present
- ground water should be drained away from a structure's foundation to a natural outfall, dry well, or storm drainage system



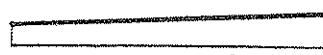
- natural surface drainage patterns are least disturbed by lifting a structure off the ground plane with piers



- always slope the ground plane away from a building to avoid water leakage problems
- to prevent soil erosion, planted ground covers should be provided for swales with grades over 3% and for ground slopes with grades over 33%

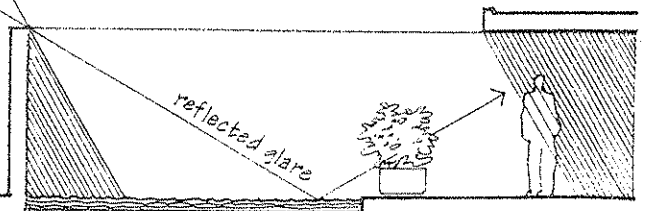


- minimum grade for planted ground cover areas: 2% (3% recommended)

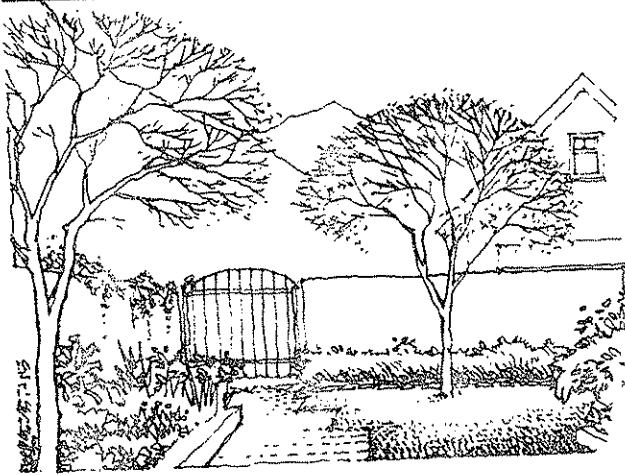


- minimum grade for paved areas: 0.5% (1% recommended)

- bodies of water can moderate temperature variations and temper their immediate environment
- in hot-dry climates, even small bodies of water are desirable, both psychologically and physically, for their evaporative cooling effect
- protection from reflected glare should be provided

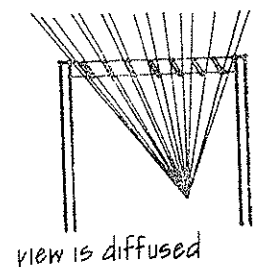
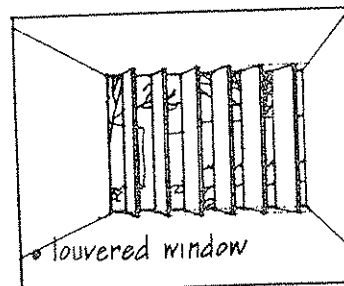
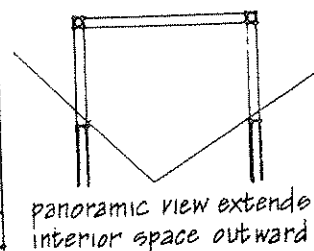
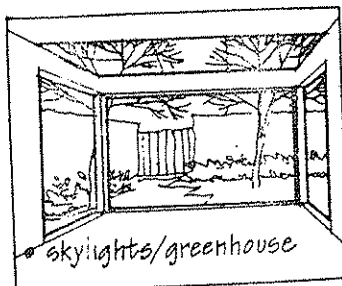
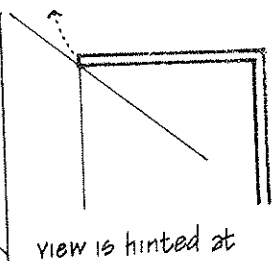
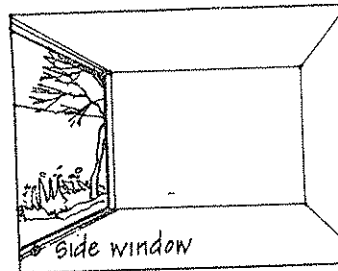
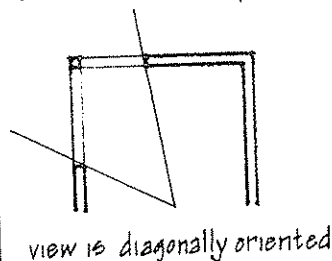
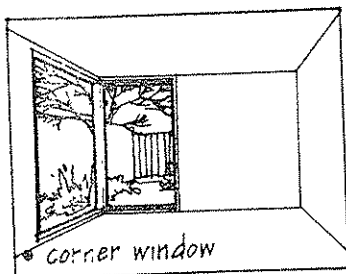
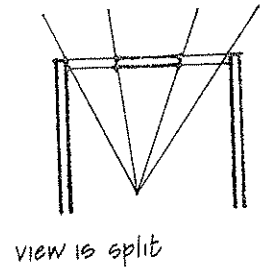
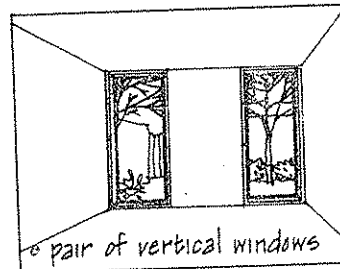
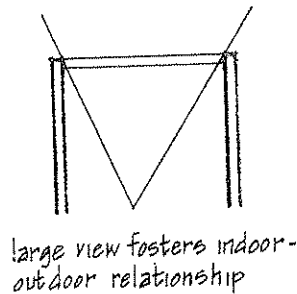
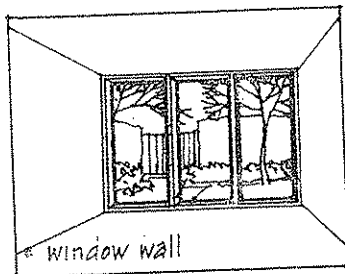
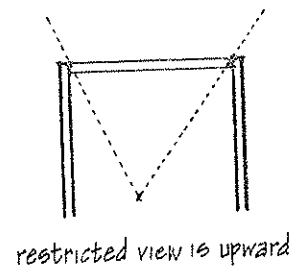
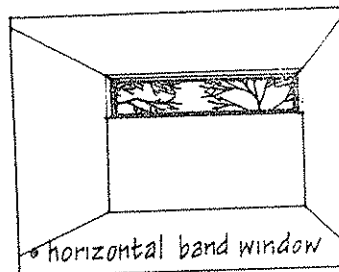
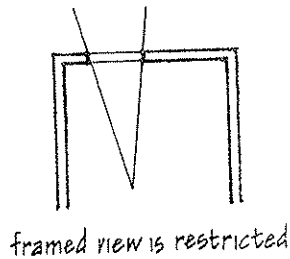
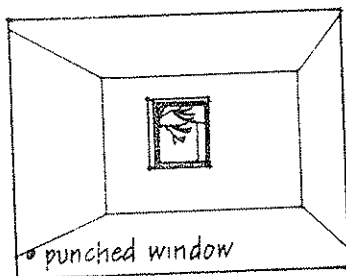


1.16 VIEWS



A building's window openings should be positioned not only to satisfy natural light and ventilation requirements but also to frame desirable views. Depending on a site's context, these views may be close or distant in nature. Even when desirable views are nonexistent, a pleasant outlook can often be created within a building site.

A window may be created within a wall in a number of ways, depending on the nature of the view and the way it is framed in the wall's construction. It is important to note that the size and location of windows also affects a room's spatial quality, daylighting, and potential heat loss or gain.

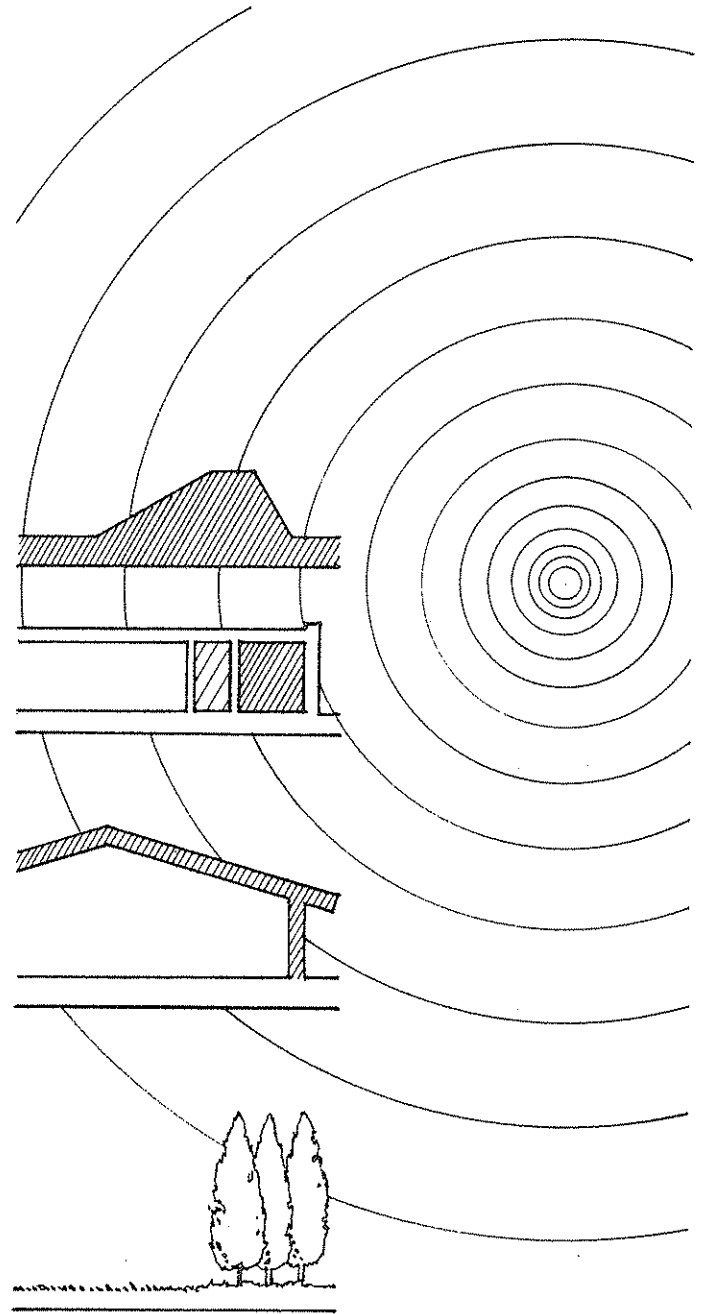


SOUND

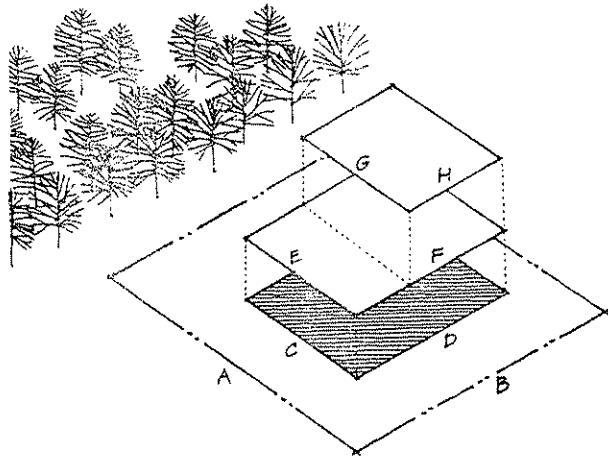
1.17

Sound requires a source and a path. Undesirable exterior sounds or noise are caused by vehicular traffic, aircraft, and other machinery. The sound energy they generate travels through the air outward from the source in all directions in a continuously expanding wave. This sound energy, however, lessens in intensity as it disperses over a wide area. To reduce the impact of exterior noise, therefore, the first consideration should be distance—locating a building as far from the noise source as possible. When a site's constraints do not make this possible, then the interior spaces of a building may be screened from the noise source by:

- physical mass such as earth berms
- building zones where noise can be tolerated: eg. mechanical, service, and utility areas
- the construction of exterior walls and roof, which are a building's primary barriers against exterior noise; door and window openings are the weak spots in these barriers and should, if possible, be oriented away from undesirable noise sources
- dense plantings of trees and shrubs, which can be effective in diffusing or scattering sound
- grass or ground covers, which are more absorptive than the hard, reflective surfaces of pavement



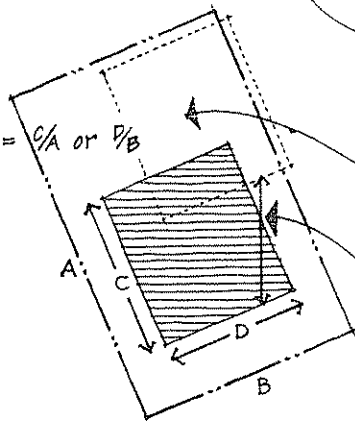
1.18 ZONING ORDINANCES



$$\% \text{ allowable lot coverage} = \frac{C \times D}{A \times B}$$

$$\% \text{ allowable total floor area} = \frac{(C \times D) + (E \times F) + (G \times H)}{A \times B}$$

$$\% \text{ allowable width or depth} = C/A \text{ or } D/B$$



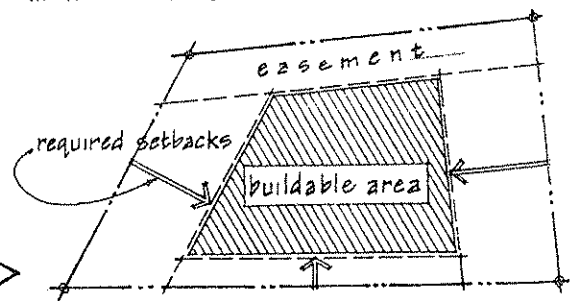
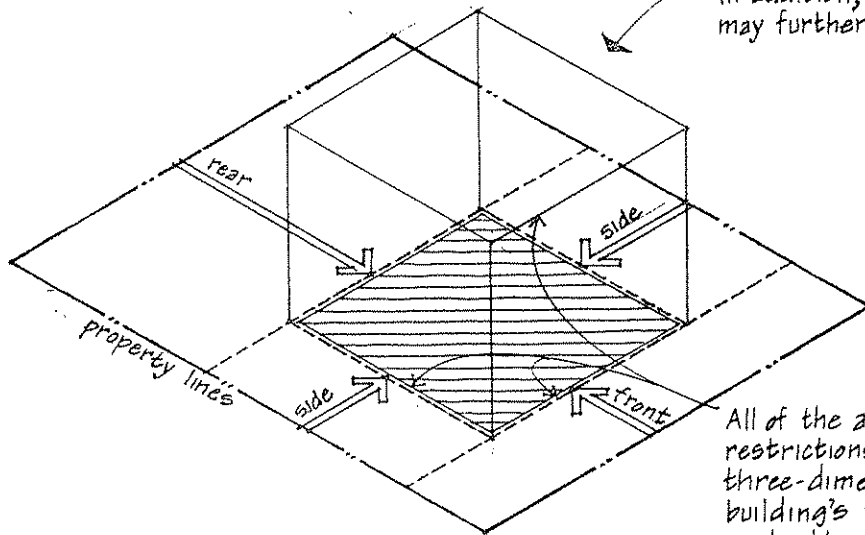
Within a municipality or land-use district, zoning ordinances are generally intended to manage growth, regulate land-use patterns, control building density, direct development to areas with adequate services and amenities, protect environmentally sensitive areas, and conserve open space.

For any single building site, a zoning ordinance will regulate both the types of activity that may occur on it and the bulk of the building(s) constructed to house such activities. A special type of zoning ordinance is the Planned Unit Development, which allows a fairly large tract of land to be developed as a single entity for added flexibility in the placement, grouping, size, and use of structures.

It is important to understand how a zoning ordinance might constrain the allowable size and shape of a building. The bulk of a building is regulated directly by specifying:

- how much of the land can be covered by a building structure and the total floor area that may be constructed, expressed as percentages of the lot area
- the maximum width and depth a building may have, expressed as percentages of the site's dimensions
- how tall the building structure can be

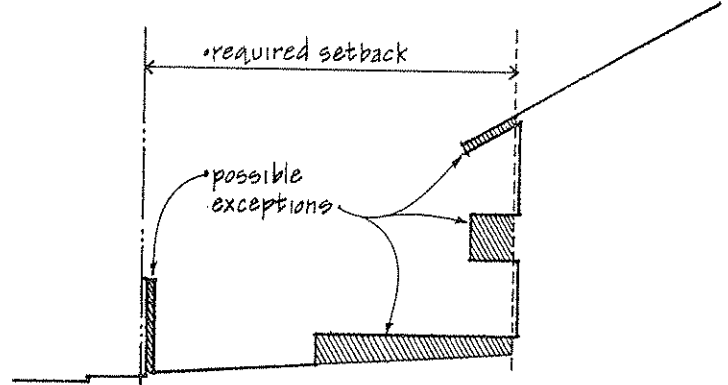
The size and shape of a building are also controlled indirectly by specifying how far a building must be set back from each of the property lines. In addition, existing easements and right-of-ways may further limit the buildable area of a site.



All of the above requirements, together with any restrictions on type and density of use, define a three-dimensional envelope beyond which a building's volume may not extend. Check the applicable zoning ordinance for specific requirements.

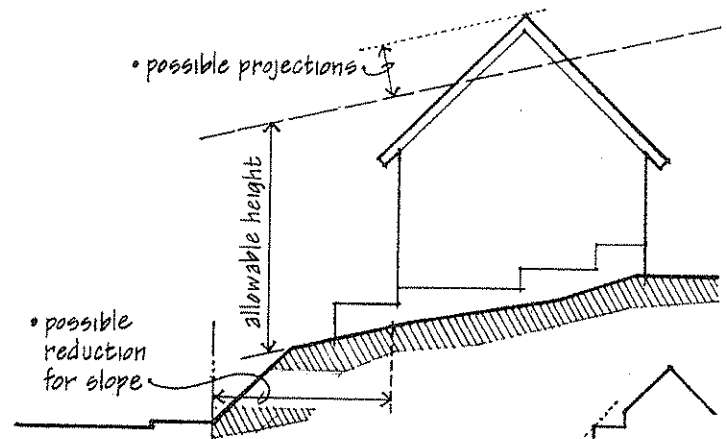
Exclusions to the general requirements of a zoning ordinance may exist in the form of exceptions or allowances. Exceptions to the normal setback requirements are typically made for:

- projections of architectural features such as roof overhangs, cornices, bay windows, and balconies
- accessory structures such as low-level decks, fences, and detached carports
- precedents set by existing, neighboring structures



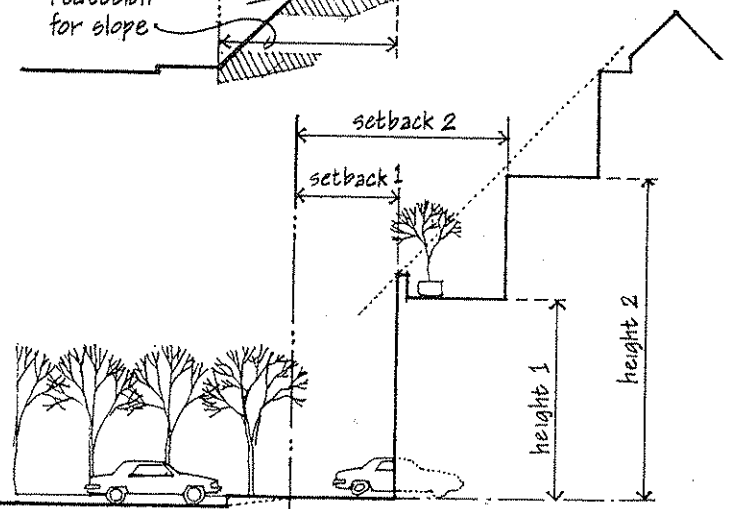
Exceptions are often made for sloping sites, or for sites adjacent to public open spaces.

- sloping roofs, chimneys, and other roof projections may be allowed to extend beyond the normal height limitation
- the height limit may be directly related to the slope of a site
- a reduction in the setback requirements may be made for sloping sites or for sites fronting on open space



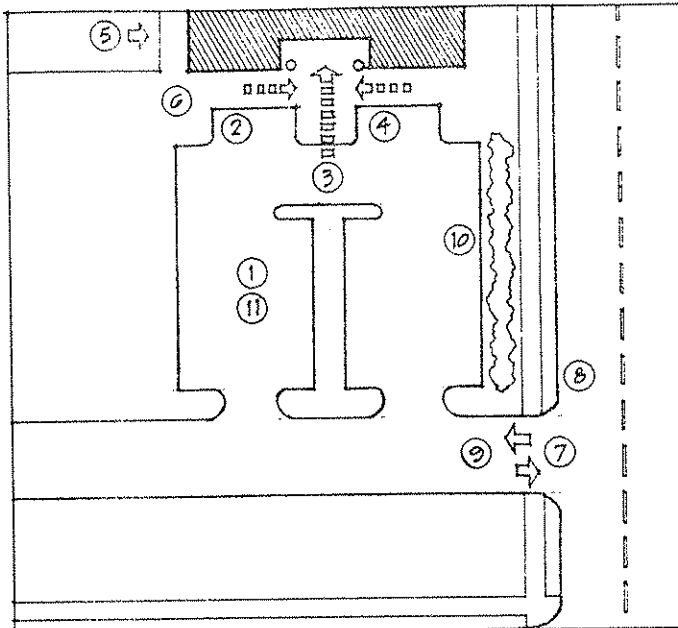
In order to provide for adequate light, air, and space, and to enhance the streetscape and pedestrian environment, requirement may exist for:

- open space accessible to the public
- additional setbacks if a structure rises above a certain height
- modulation of a building's facades
- vehicular access and parking



Zoning ordinances may also contain requirements that apply only to specific use categories as well as procedures for requesting a variance from the regulations.

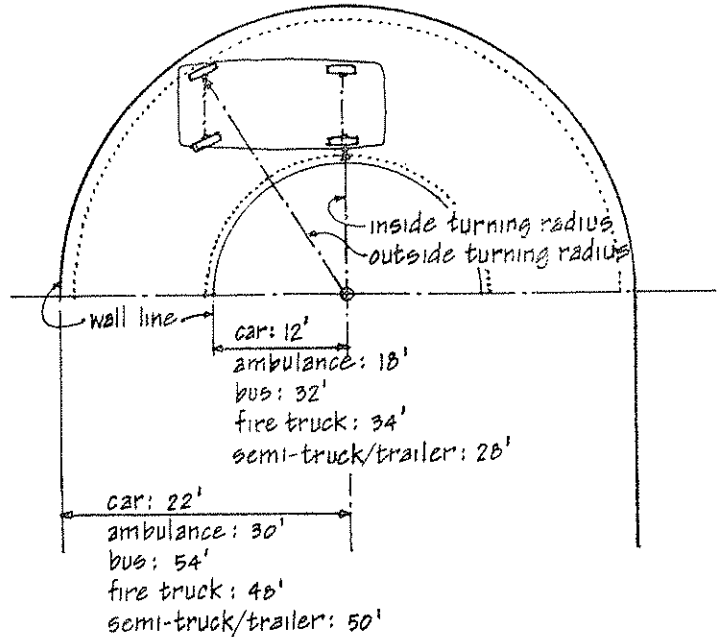
1.20 VEHICULAR ACCESS AND PARKING



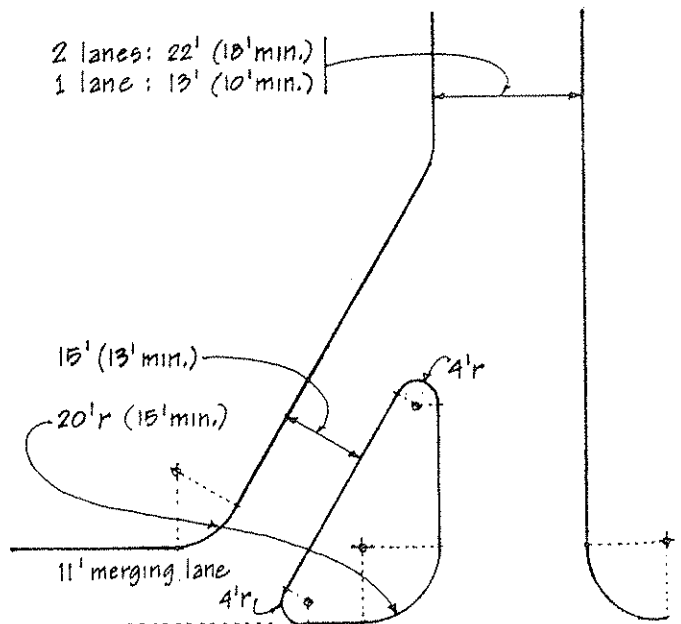
Providing for vehicular access and parking are important aspects of site planning which influence both the location of a building on its site and the orientation of its entrances. Outlined on these pages are some fundamental criteria for estimating the space required for roadways and surface parking. Any planning of vehicular access and parking must take into consideration the safe and convenient movement of pedestrians about a site and from parking to building entrances.

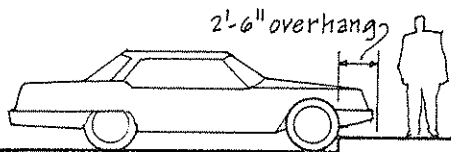
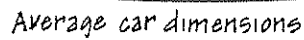
PLANNING CONSIDERATIONS:

1. number of parking spaces required by zoning ordinance is based on type of occupancy; may be related to number of living units or to floor area of building
2. number, size, and location of spaces for the handicapped; curb cuts and ramps for wheelchair access
3. pedestrian access to building entrances from parking areas
4. loading zones for buses and other public transportation vehicles
5. separation of service and truck loading areas
6. access for emergency vehicles such as fire trucks
7. allowable width and location of curb cuts, and distance from public street intersections
8. clear sight lines for vehicles entering public roadway
9. control of access to parking areas
10. space for landscaping; screening of parking areas may be required by zoning ordinance
11. drainage of parking surfaces; space for snow removal

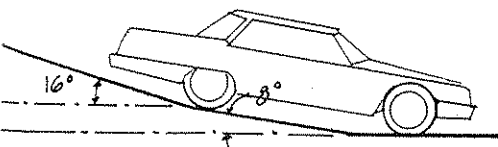
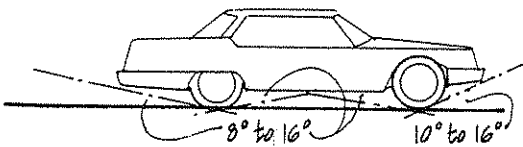
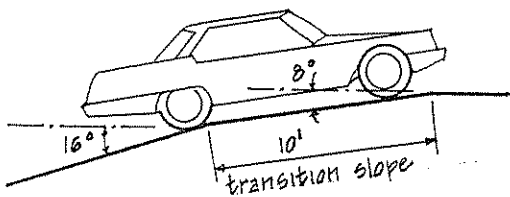


2 lanes: 22' (18' min.)
1 lane: 13' (10' min.)

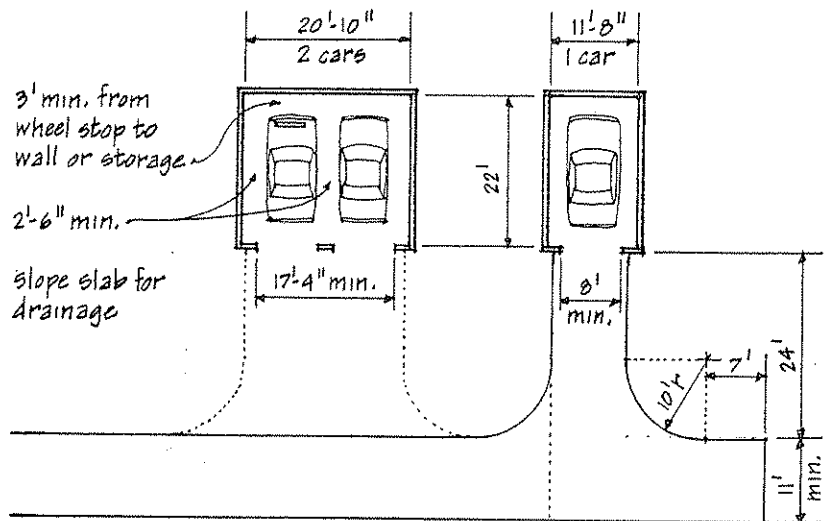




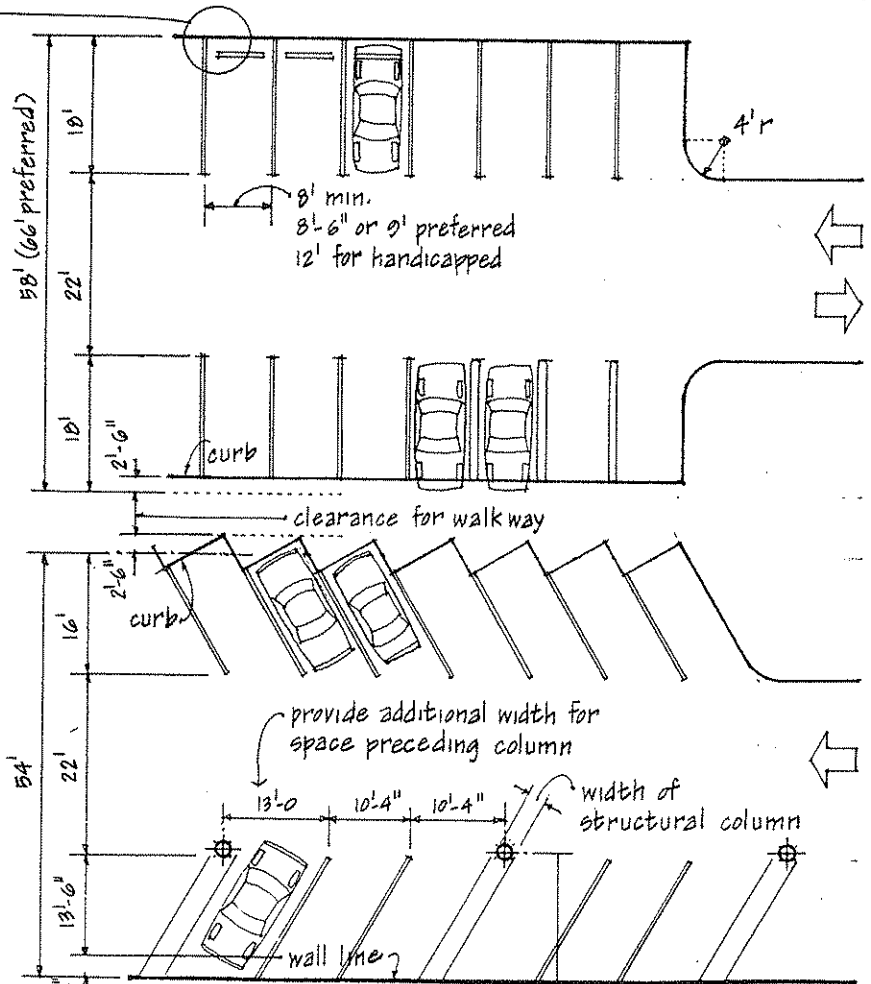
Basic parking space is 8'-6" x 18'-0".
Adjust width for compact cars
and allow for opening of car doors,
carrying of parcels, and handicapped
access.



CAR RAMP SLOPES



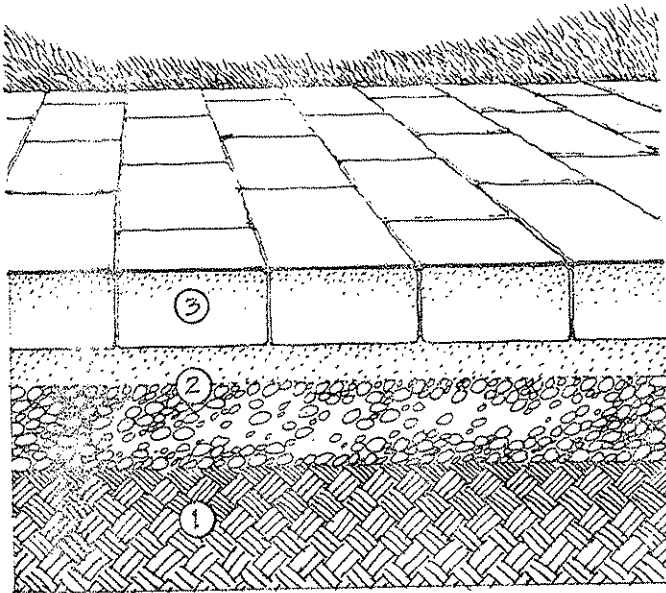
RESIDENTIAL DRIVES AND GARAGES



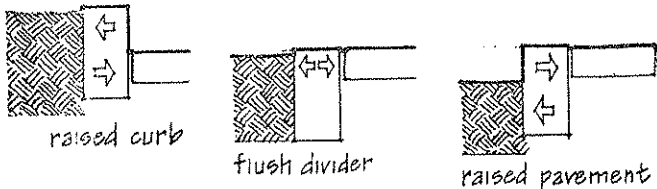
PARKING LOT DIMENSIONS

1.22

PAVING



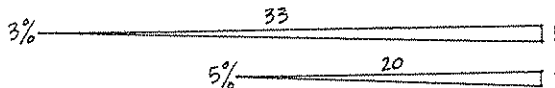
- ① The subgrade, which must ultimately carry the pavement load, should be undisturbed soil or compacted fill. Since it also receives moisture from infiltration, it should be sloped to drain.
- ② The base is a foundation of well-graded aggregate that transfers the pavement load to the subgrade. It also prevents the upward migration of capillary water. Heavy-duty loads may require an additional layer – a subbase of coarser aggregate such as crushed stone.
- ③ The pavement receives the traffic wear, protects the base, and transfers its load to the base structure. There are two types of pavement: flexible and rigid. Flexible pavements, such as bituminous concrete or unit pavers on a sand setting bed, are somewhat resilient and distribute loads to the subgrade in a radiating manner. Rigid pavements, such as reinforced concrete slabs or paving units mortared over a concrete slab, distribute their loads internally and transfer them to the subgrade over a broad area. Rigid pavements generally do not require as thick a base as flexible pavements.



EDGE CONDITIONS

SLOPE FOR DRAINAGE

0.5% min.; 1% preferred;
highly textured pavements may require a
steeper (2%) slope for drainage.



SLOPES: 0% - 3% preferred; 5% maximum



RAMPS: 5% - 8% ; use only where climatic
conditions permit

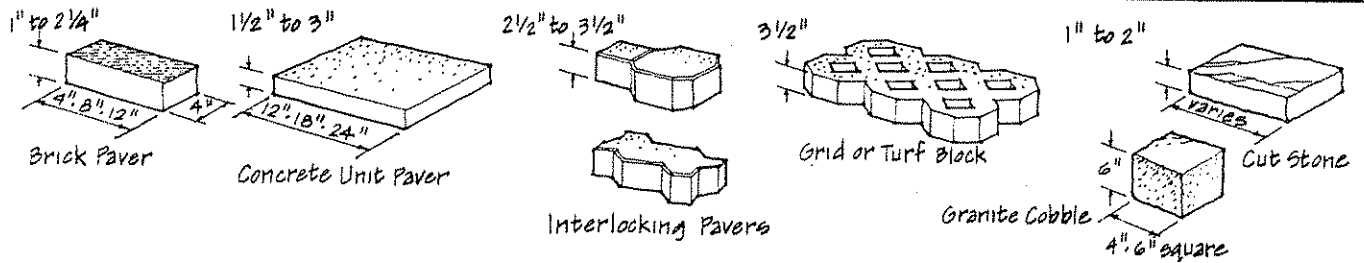
Flexible pavements require wood, steel, stone, masonry, or concrete edging to restrain the horizontal movement of the paving material. Rigid pavements require reinforcement and an extension of the base material along their edges.

Additional notes:

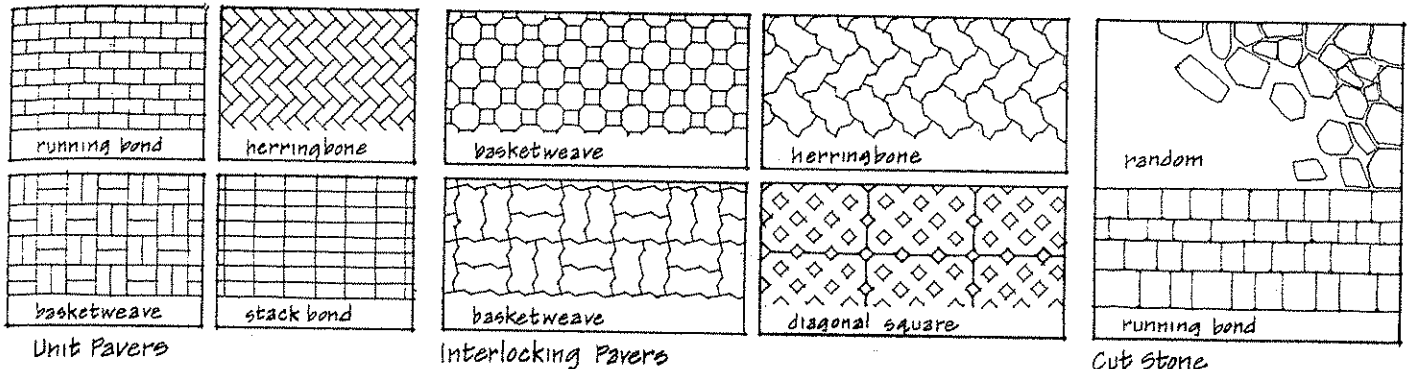
- Pavement color and texture are important aesthetic considerations which also affect the pavement's absorption or reflection of heat and light.
- Provide traction for ramps and pavements in areas subject to icy conditions.
- Avoid surface irregularities for wheelchair traffic.
- Provide tactile warning strips for the visually impaired at grade changes and hazardous vehicular areas.

UNIT PAVING DETAILS

1.25



PAVING MATERIALS: Consult local supplier for availability of shapes, sizes, colors, textures, absorption properties, compressive strength, and installation recommendations.



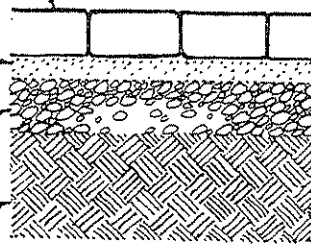
PAVING PATTERNS

brick or conc. pavers w/ handtight or 1/8" - 1/4" sand swept joints

1" - 2" sand setting bed

2" - 6" compacted aggregate where required in high traffic areas or over expansive soil

compacted subgrade or undisturbed soil



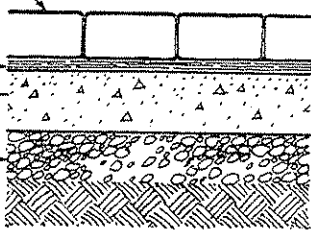
FLEXIBLE BASE

unit pavers as above

3/4" bituminous setting bed

4" - 6" conc. slab

compacted aggregate, if req'd.



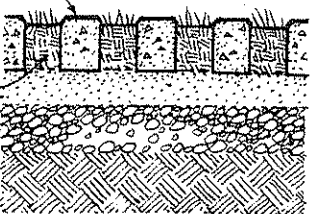
RIGID BASE

turf block

topsoil mix for grass or ground cover

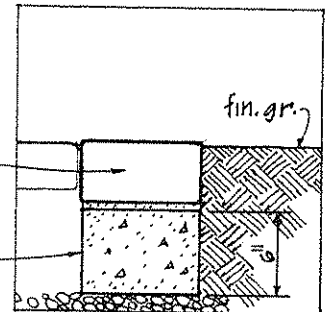
2" sand setting bed

2" - 6" compacted aggregate



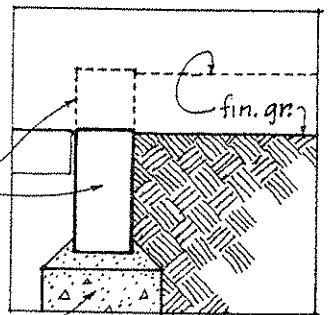
paving unit on mortar bed, set on edge or laid flat

conc. grade beam w/ exp. jts.



paving unit set vertically on mortar bed - may extend up to 1/2 of paver ht. to form curb

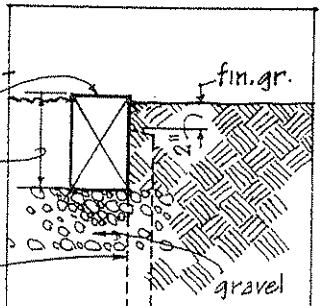
conc. or mortar ft'g. (provide gravel under footing if frost depth is deeper than footing)



2x, 4x, or 6x pressure-treated wood edge

depth varies w/ paving material

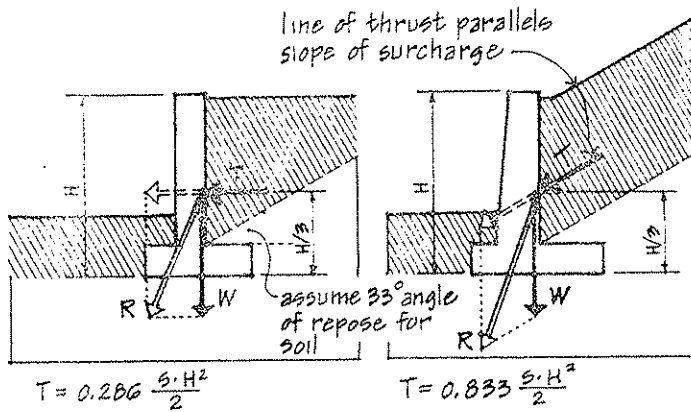
2x2 or 2x4 pt. wood stakes, 24" long, @ 3' - 4' o.c.



EDGE CONDITIONS

PAVING DETAILS

1.24 RETAINING WALLS



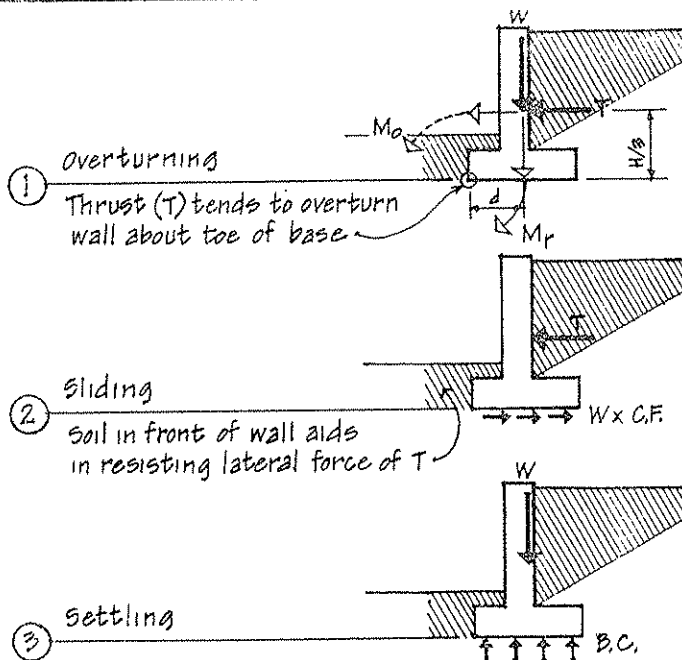
S = weight of soil (100 lb./ft³ typical)

W = composite weight of wall acting through centroid of section

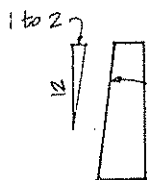
R = resultant of T and W

Retaining walls are used to create relatively level areas and to allow changes in elevation which cannot be accomplished by grading within the horizontal dimensions of a site. They must be constructed to resist the thrust of the soil being retained. This thrust can cause a retaining wall to fail in three ways.

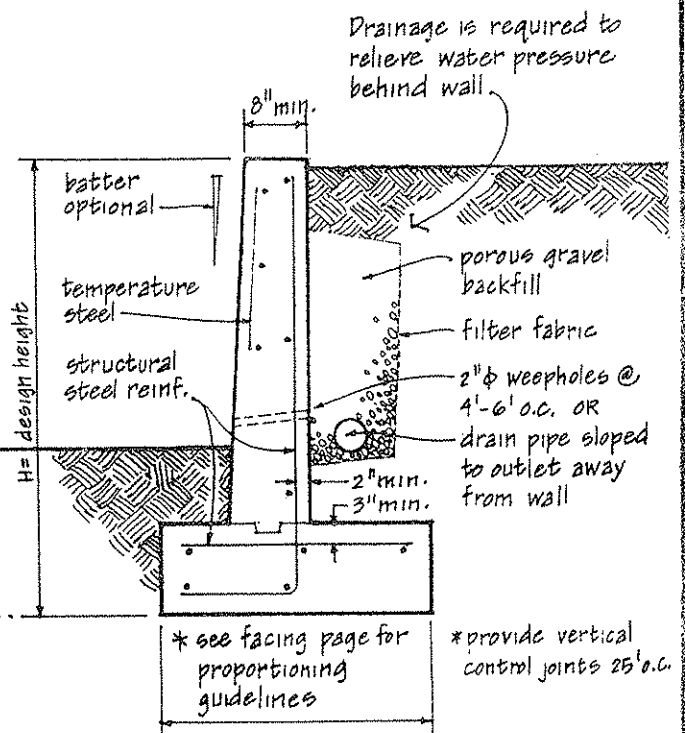
- ① **Overturning:** The overturning moment (M_o) of the soil thrust ($T \times H/3$) must be countered by the resisting moment (M_r) of the composite weight of the wall and any soil bearing on the base ($W \times d$). Using a safety factor of 2, $M_r \geq 2 M_o$
- ② **Sliding:** The lateral thrust on the wall (T) must be resisted by the composite weight of the wall times the coefficient of friction for the soil supporting the wall ($W \times C.F.$). Using a safety factor of 1.5, $W \times C.F. \geq 1.5 T$
- ③ **Settling:** The bearing capacity of the soil (B.C.) must not be exceeded by the vertical force ($W =$ weight of the wall and any soil bearing on the base plus the vertical component of the soil thrust for a wall with surcharge). Using a safety factor of 1.5, $B.C. \geq 1.5 W/A$.



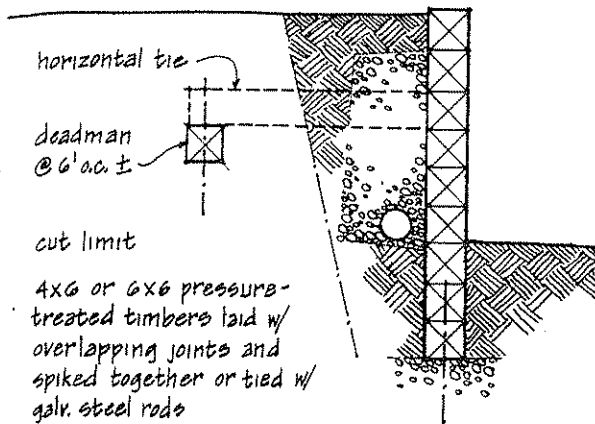
Footing should extend 2' below the lower grade OR to below the frost line, whichever is greater



Batter refers to the sloping face of a wall which can offset the illusion of a vertical face leaning forward

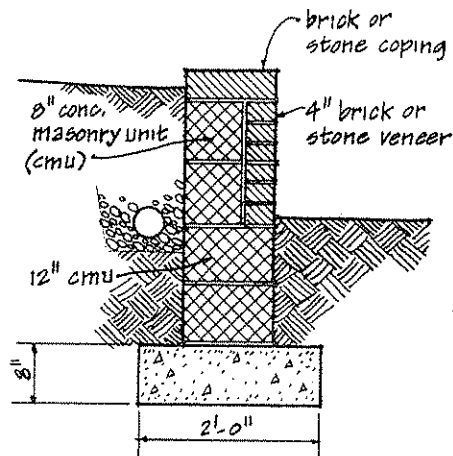


REINFORCED CONCRETE RETAINING WALL

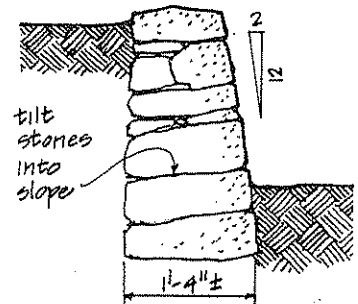


HORIZONTAL TIMBER WALL

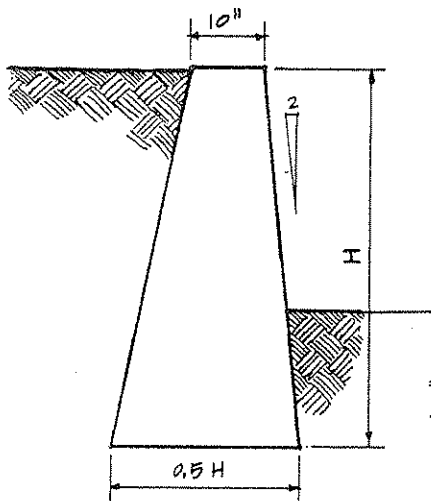
Timber, stone, and brick may be used for relatively low retaining walls. For retaining walls over 4 feet high, reinforced concrete is more commonly used. The proportioning guidelines below are for preliminary design only. Consult a structural engineer for final design, especially when a retaining wall is built on poor soil or subject to surcharge or live loads.



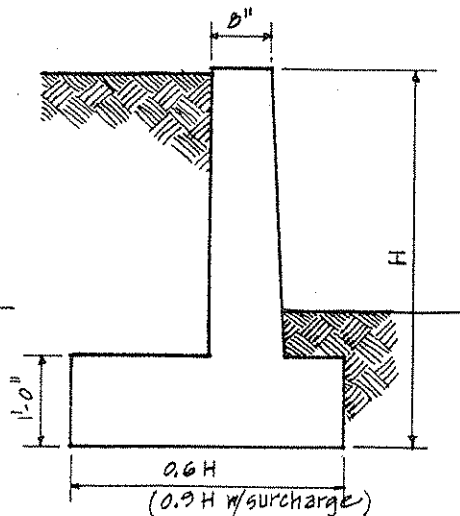
BRICK OR STONE VENEER WALL



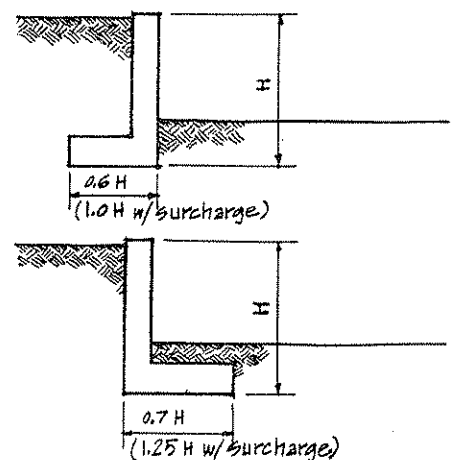
DRY STONE WALL



GRAVITY WALL

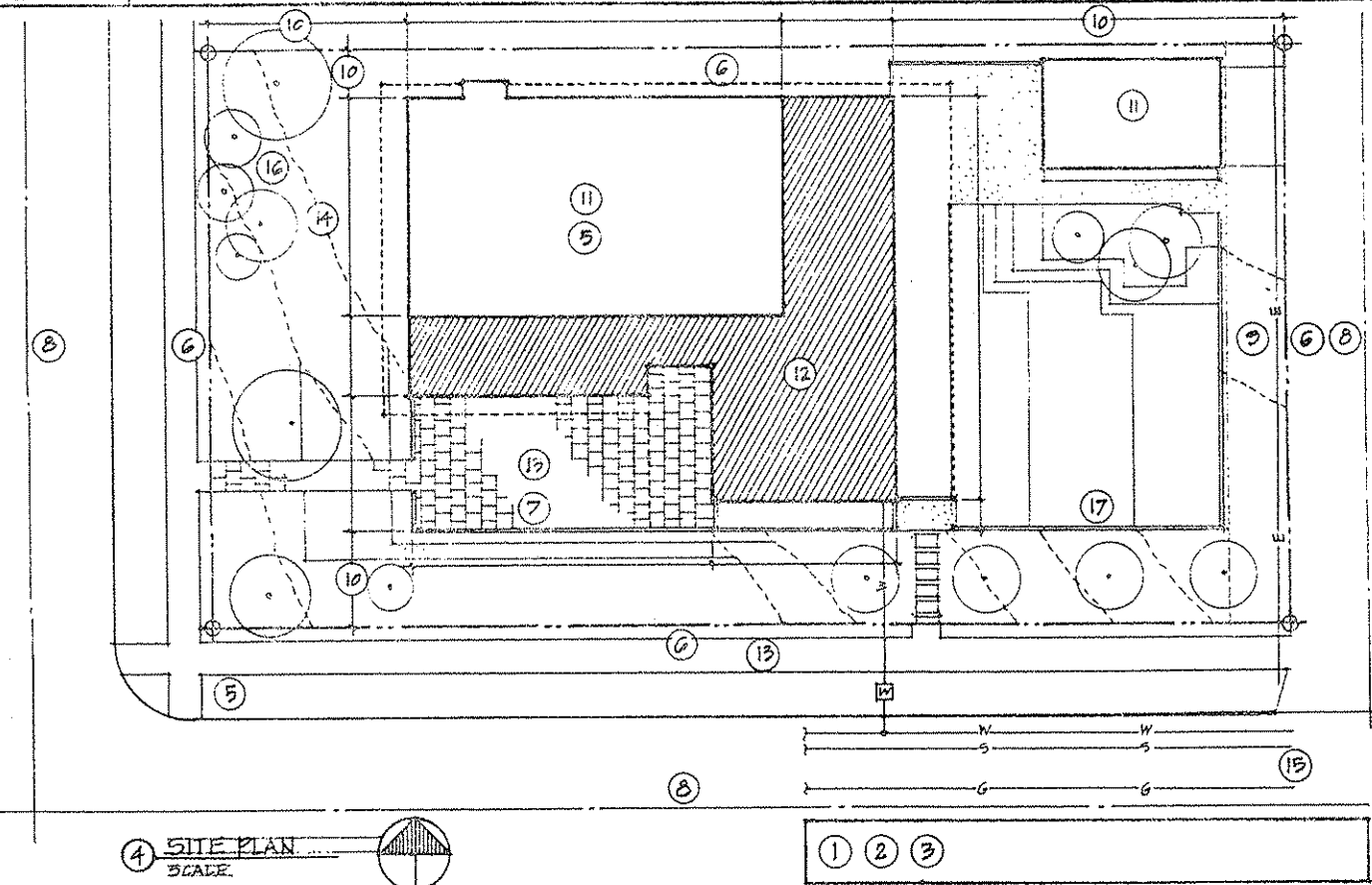


T-TYPE CANTILEVERED WALL



L-TYPE WALLS

1.26 THE SITE PLAN

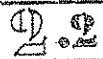


The site plan illustrates the existing natural and built features of a site and describes proposed construction in relation to the existing features. Usually based on an engineer's land survey, the site plan is essential for studying the influence of environmental and regulatory factors on the planning, siting, and massing of a building. A site plan should include the following items:

1. Name and address of property owner
2. Address of property, if different from owner's address
3. Legal description of property
4. North arrow and scale of drawing
5. Bench marks which establish the reference points for the location and elevations of new construction
6. Description of the site's boundaries: dimensions of property lines and their bearing relative to north, angles of corners, radii of curves
7. Project limits, if different from site boundaries
8. Identification of adjacent streets, alleys, and other public right-of-ways
9. Location and dimensions of any easements that cross the site or other pertinent legal features
10. Dimensions of setbacks required by the zoning ordinance
11. Location and size of existing structures and a description of any demolition required by the new construction
12. Location, shape, and size of structures proposed for construction, including roof overhangs and other projections
13. Location and dimensions of existing and proposed paved drives, parking areas, and walkways
14. Existing ground elevations and contour lines, and, where regrading is necessary, new contour lines
15. Location of existing utility lines (electric, gas, water, sewer) and proposed hookup points
16. Existing plant materials to remain and those to be moved
17. Proposed landscaping features, such as fencing and plantings
18. Existing water features, such as drainage swales, creeks, or shorelines
19. References to other drawings and details

THE BUILDING

This chapter begins by outlining the major types of drawing which we use to develop and communicate design ideas. The subject of this discussion then serves to illustrate a building as the embodiment of a number of necessarily related, coordinated, and integrated systems. This series of illustrations provides a context for the following chapters, each of which takes a major building component, illustrates its construction in various materials, and describes how it relates to other components. Included in this chapter is a brief introduction to a building's structure, the system which both figuratively and physically holds all of the other building systems together.

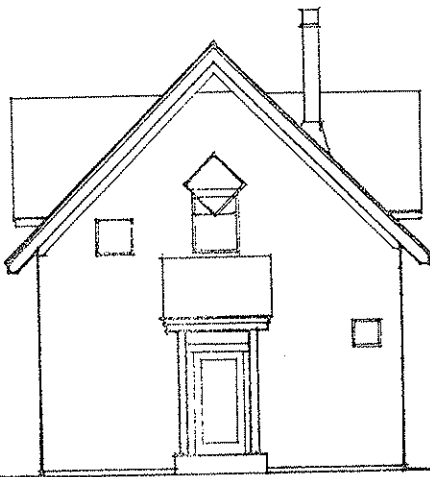


ARCHITECTURAL DRAWINGS

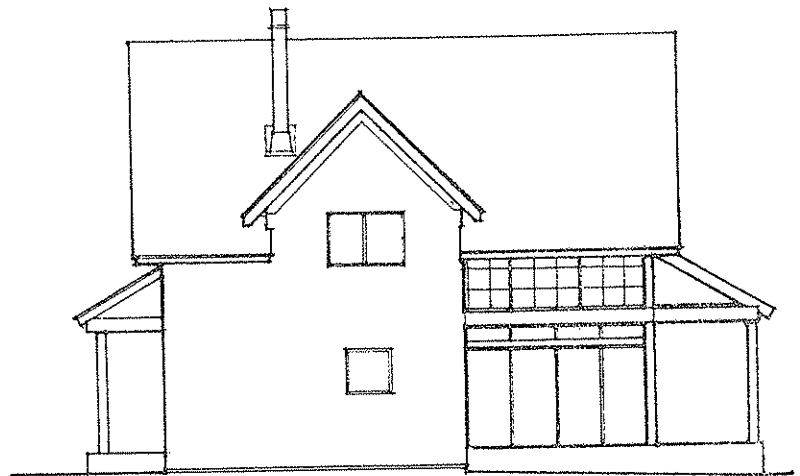
Architectural drawings make up the graphic language of building design and construction. In the design process, drawings are used to visualize possibilities, study alternatives, and present design ideas about the form and spaces of a building. For the execution of a design, construction or "working" drawings are necessary to accurately describe the constituent parts of a building, articulate their relationships, and reveal how they go together.

Construction drawings consist primarily of plan, section, and elevation views, which are orthographic projections onto a perpendicular drawing surface. These are also called multiview drawings since a series of related views is required to understand the three-dimensional form of a design and its constituent parts. The main advantage of this type of drawing, and the reason why it is used in building construction, is that building elements are seen in true size (to scale), shape, and orientation when viewed from a perpendicular aspect. Orthographic drawing's main disadvantage is its inherent ambiguity in the definition of depth or the third dimension. For this reason, reliance on conventions and symbols is necessary for the description and understanding of what is drawn.

Orthographic plans, sections, and elevations are used not only to portray whole building forms but also to describe the form and construction of a building's components, such as in wall sections, window details, and cabinet drawings. See 2.5.



NORTH ELEVATION

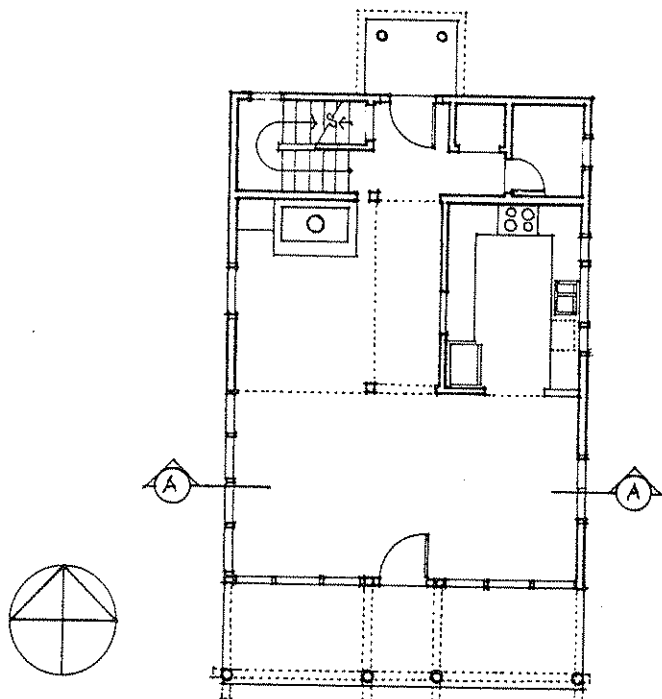


WEST ELEVATION

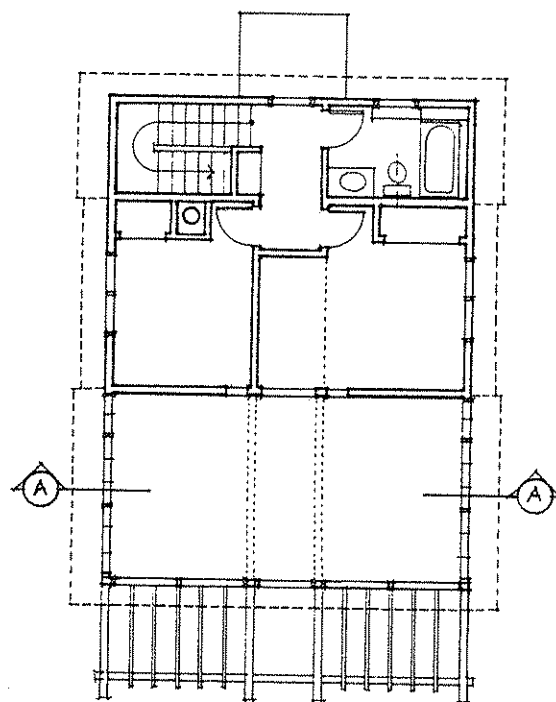
The site plan is a view looking down at a building from above, illustrating its location and orientation on a plot of land and providing information about the site's topography, landscaping, utilities, and sitework. See 1.26.

The floor plan is also a view looking down, but after a horizontal plane is cut through a building about 4 feet above the floor plane and the top section removed. It illustrates the horizontal dimensions of a building's spaces, as well as the thickness and construction of the vertical walls and columns that define these spaces.

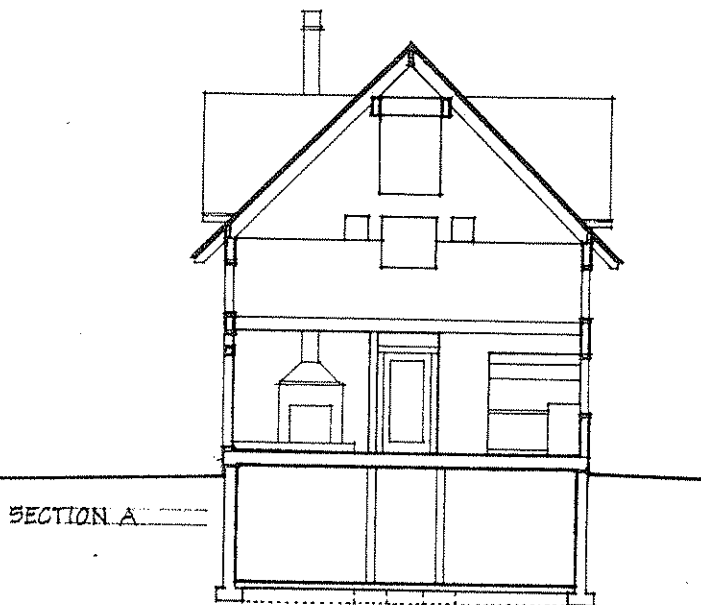
ORTHOGRAPHIC VIEWS



FIRST FLOOR PLAN



SECOND FLOOR PLAN



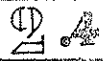
SECTION A



SOUTH ELEVATION

The building section is a horizontal view after a vertical plane is cut through a building and the front portion removed. It reveals the vertical and, in one direction, the horizontal dimensions of a building's spaces. While it illustrates primarily the thickness and construction of floors, roofs, and walls, it may also include exterior and interior elevations seen beyond the plane of the cut.

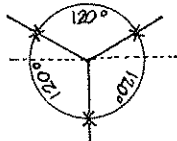
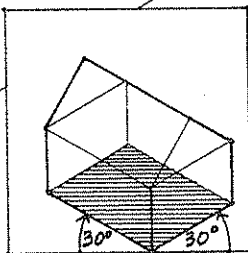
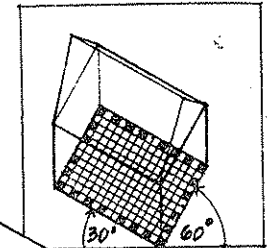
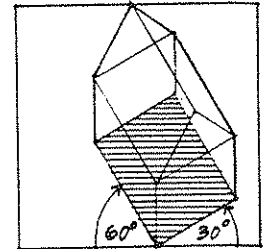
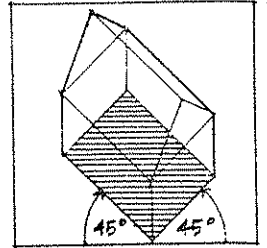
Building elevations are horizontal views of a building's exterior, usually taken from a point of view perpendicular to the principal vertical surfaces. They illustrate the size, shape, and materials of the exterior surfaces as well as the size, proportion, and nature of the door and window openings within them.



PARALINE VIEWS

Plan oblique views are projected from an orthographic view of a horizontal floor or ground plane, which is oriented at some angle to the horizontal ($45^\circ/45^\circ$, $60^\circ/30^\circ$, $30^\circ/60^\circ$). The orientation we use determines how much we see of each plane.

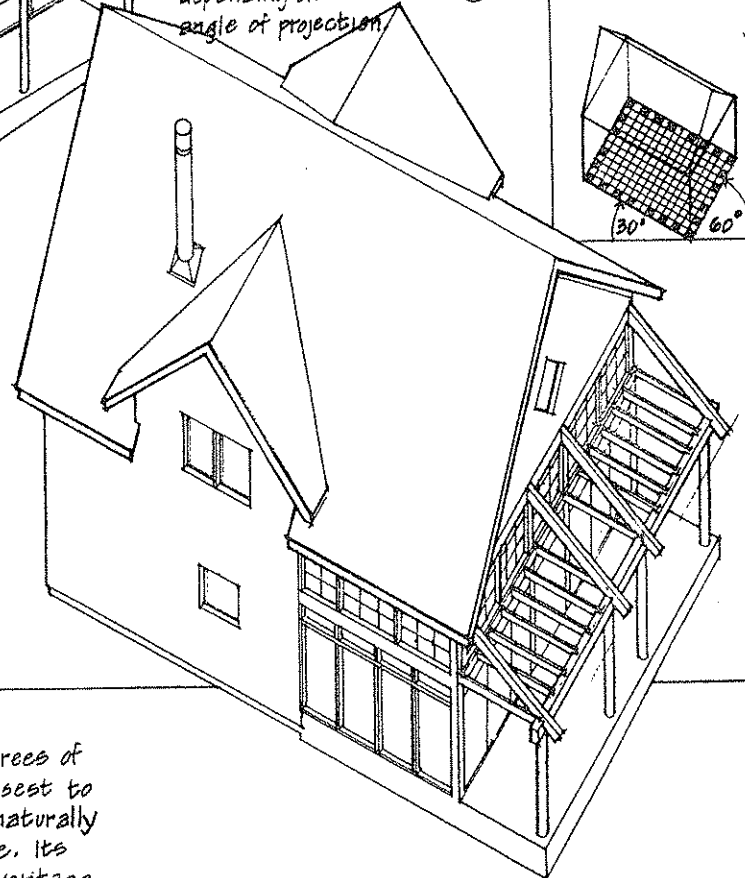
Elevation obliques are similar but projected from an elevation. Depth is usually foreshortened depending on the angle of projection.

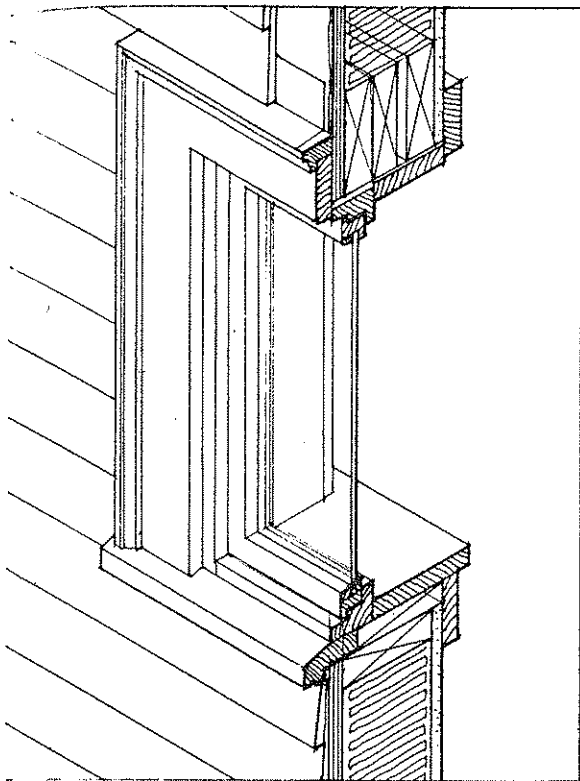


Isometric views are projected along x-, y-, and z-axes which are 120° apart on the picture plane. If verticals remain vertical, then the x- and y-axes are each drawn 30° to the horizontal. Isometrics are not subject to the distortion of oblique views, give a truer image of relative proportions, and are drawn from a slightly lower angle of view.

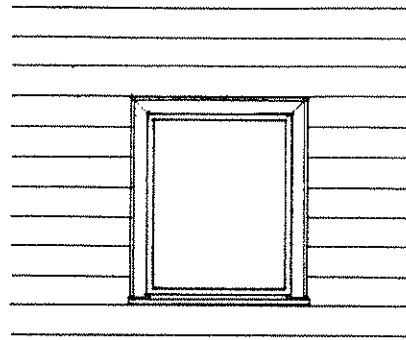
All drawing is convention utilizing varying degrees of abstraction. The type of drawing that comes closest to communicating three-dimensional form as we naturally perceive it is an accurately drawn perspective. Its pictorial value, however, cannot be taken advantage of in construction drawings since elements within the perspective are foreshortened and cannot be scaled. A type of drawing that combines the pictorial value of a perspective and the scalability of orthographic drawings is the paraline drawing. For this reason, whenever possible, graphic information in this book is presented via paraline drawings.

On this page are paraline views of the building drawn orthographically on the previous two pages. In a paraline drawing, parallel lines remain parallel and dimensions along the x-, y-, and z-axes can be drawn to scale. Note that forms in a paraline drawing are always seen from above or below.

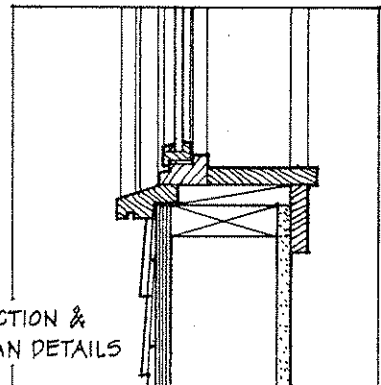
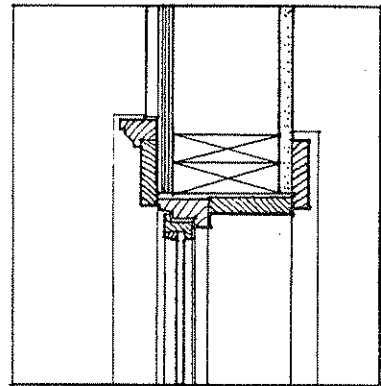
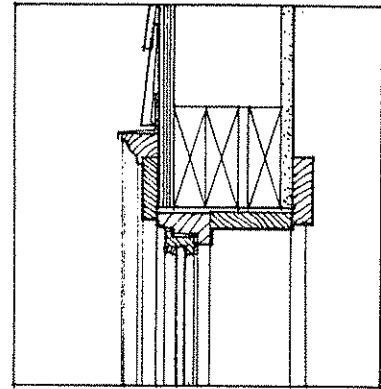




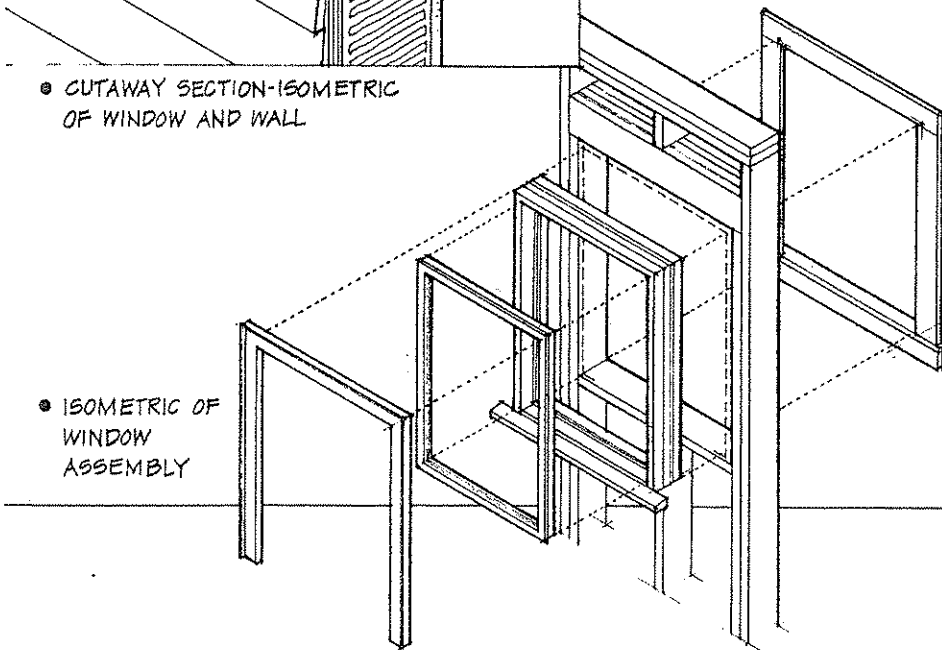
● CUTAWAY SECTION-ISOMETRIC OF WINDOW AND WALL



● ELEVATION OF WINDOW



● SECTION & PLAN DETAILS

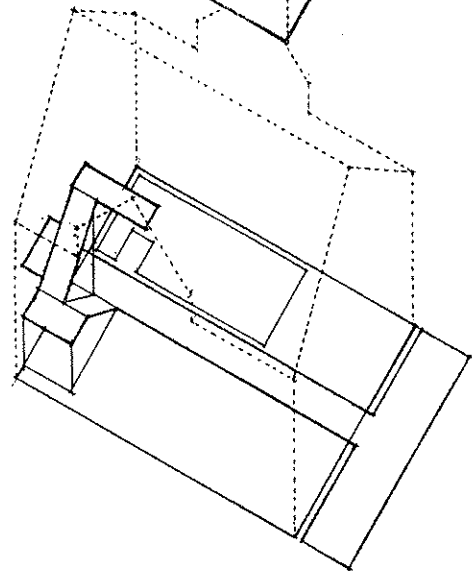
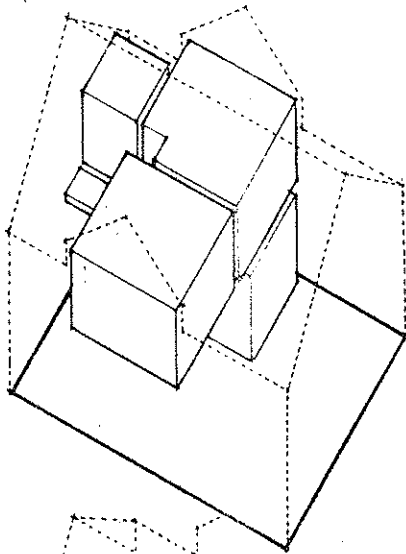


● ISOMETRIC OF WINDOW ASSEMBLY

We should be familiar with the various types of drawing conventions. Construction drawings consist primarily of plan, section, and elevation views. These orthographic drawings clearly illustrate the shape of elements when perpendicular to our line of sight and reveal their horizontal and vertical dimensions and relationships.

Parallel views can also be effective in describing—in a three-dimensional way—the parts of a building, how these elements relate to each other, and how they are assembled in construction. The choice of which drawing type to use will depend ultimately on the nature of what we want to illustrate.

2.6 BUILDING SYSTEMS

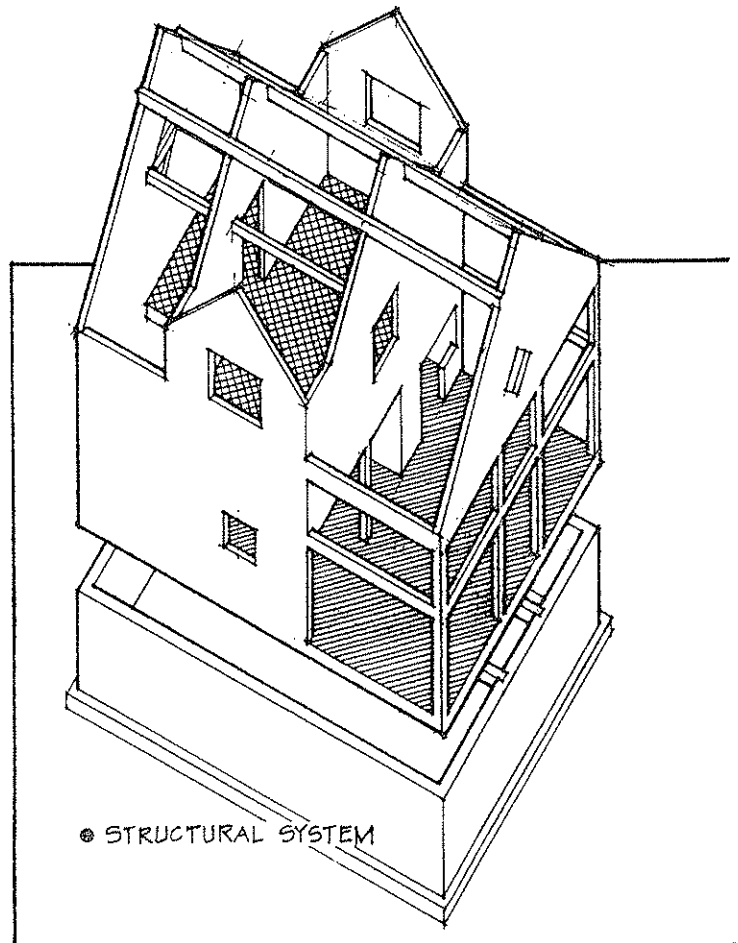


- horizontal and vertical paths of movement through a building's interior
- the physical imagery of a building: form, space, light, color, texture, and pattern
- context: the building as an integrated component within the natural and built environment

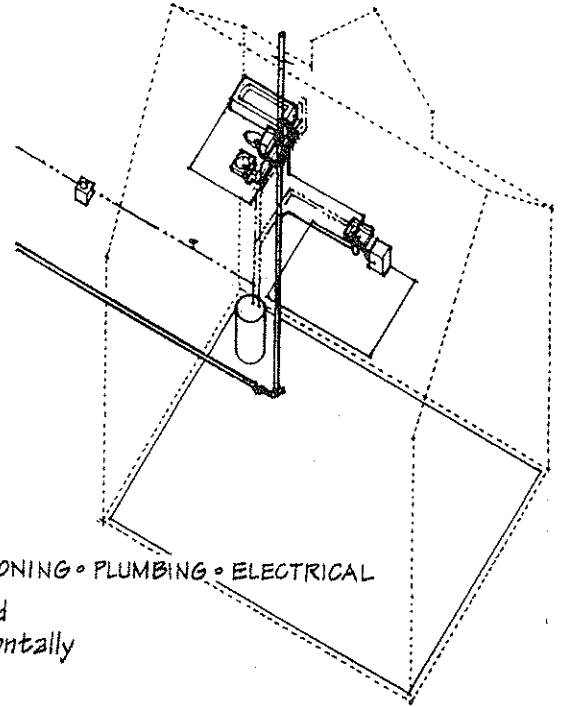
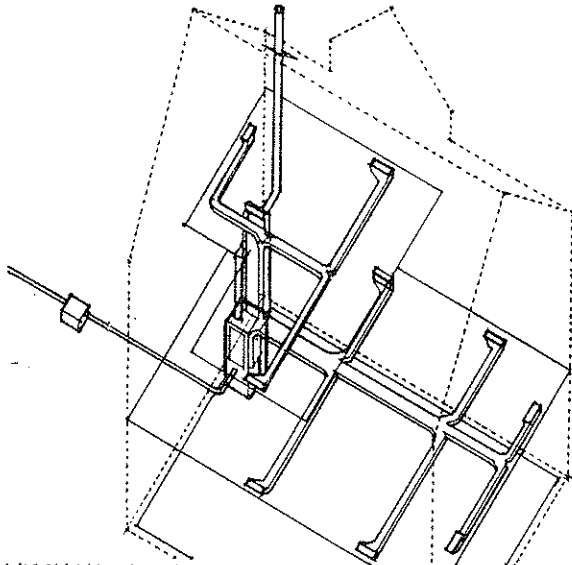
Architecture and building construction are not necessarily one and the same. An understanding of how the various elements, components, and systems of a building come together — and how they must be compatible and integrated with one another — is necessary during both the design and construction of a building. This understanding, however, enables one to build architecture but does not guarantee it. A working knowledge of building construction is only one of several critical factors in the execution of architecture.

When we speak of architecture as the art of building, we should consider conceptual systems of order in addition to the physical ones of construction.

- the definition, scale, proportion, and organization of a building's interior spaces
- the functional zoning of a building's spaces according to purpose and use

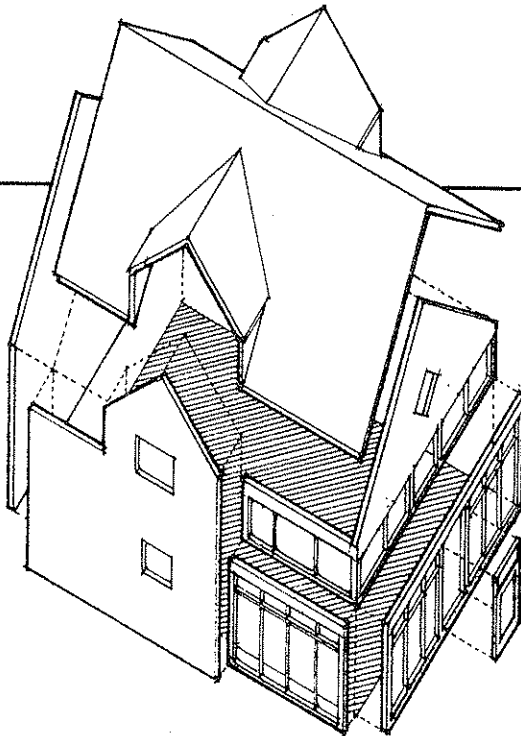


• STRUCTURAL SYSTEM



• MECHANICAL SYSTEMS: HEATING • VENTILATING • AIR CONDITIONING • PLUMBING • ELECTRICAL

The mechanical systems of a building are generally concealed from view and run vertically within wall spaces and horizontally within floor and roof systems. They must therefore be carefully integrated with each other as well as with the building's form, structure, and spatial organization.



• ENCLOSURE SYSTEM

Of primary interest to us in this book are the physical elements that define, organize, and reinforce the perceptual and conceptual ordering of a building. On the following page we will begin to break a building down into these constituent elements which will then be elaborated on in succeeding chapters. The focus of the remainder of this chapter will be a building's structural system — the configuration of structural elements that literally and figuratively holds all of the other building systems together.

2.8 BUILDING ELEMENTS

A building can generally be broken down into the following physical systems:

- ◇ STRUCTURAL SYSTEM
- ◇ EXTERIOR ENVELOPE
- ◇ INTERIOR SUBDIVISIONS OF SPACE

Each of these, in turn, can be seen to be made up of linear and planar assemblies.

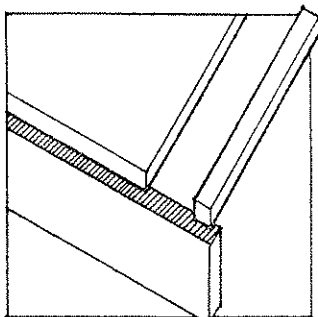
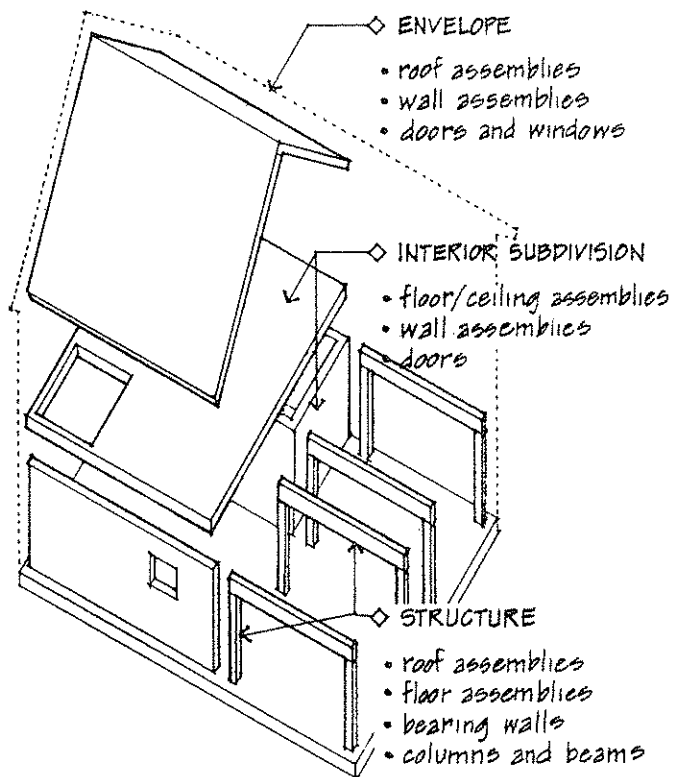
○ Planar Assemblies

- horizontal or sloping roof planes
- horizontal floor planes
- vertical wall planes

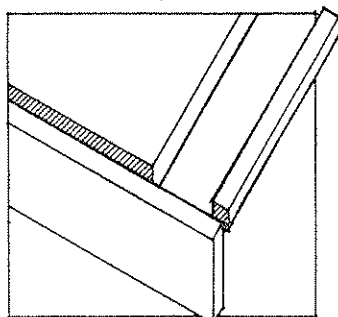
○ Linear Assemblies

- horizontal beams
- vertical columns

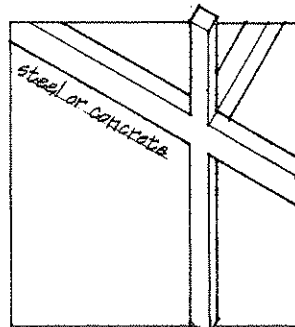
These elements and assemblies can come together in a number of ways, depending on the nature of the materials used, the method for transferring and resolving the forces acting on a building, and the desired physical form. Presented below are the basic types of connections used in building construction.



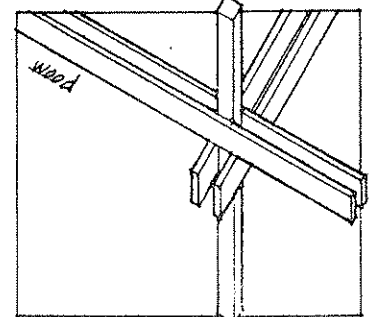
DIRECT BEARING



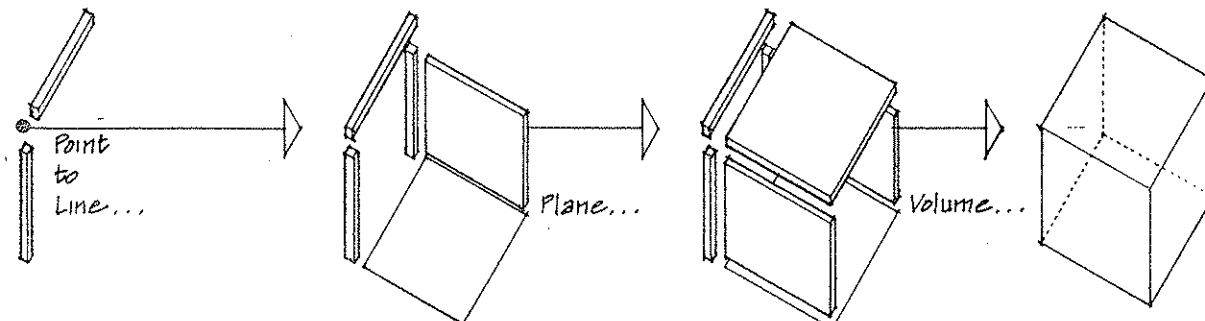
VERTICAL BUTT



RIGID/MONOLITHIC



INTERLOCKING/OVERLAPPING



A useful way of seeing the forms of building elements in a comparative manner is to categorize them according to the geometric elements of point, line, plane, and volume. These elements are joined together in construction to form a building's various components and subsystems. The drawing on the facing page illustrates these subsystems and serves as a visual index to the organization of this book.

Roof Systems
Chapter 6

Moisture and
Thermal Protection
Chapter 8

Mechanical and
Electrical Systems
Chapter 11

Doors and Windows
Chapter 7

Wall Systems
Chapter 5

Floor Systems
Chapter 4

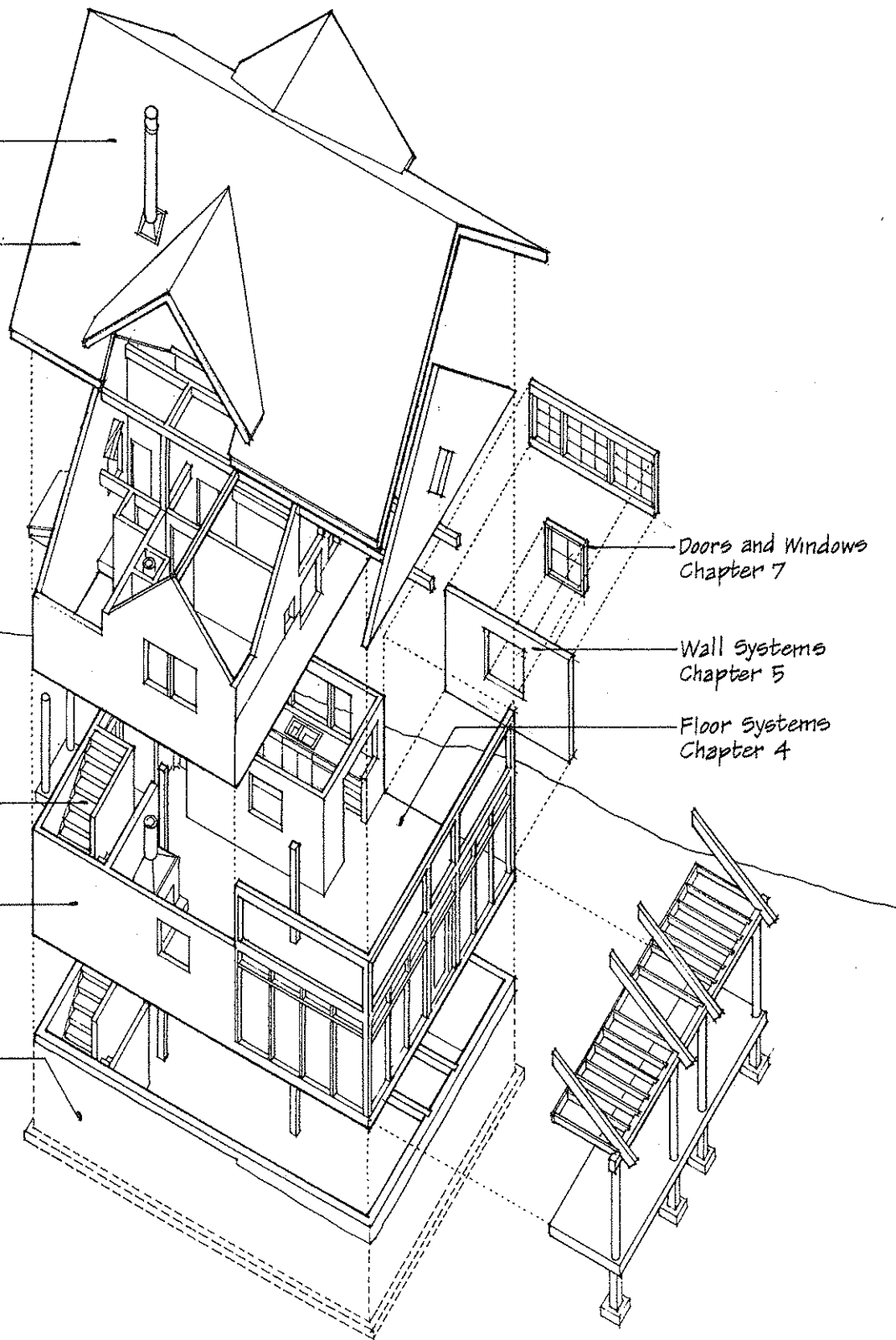
Special Construction
Chapter 9

Finish Work
Chapter 10

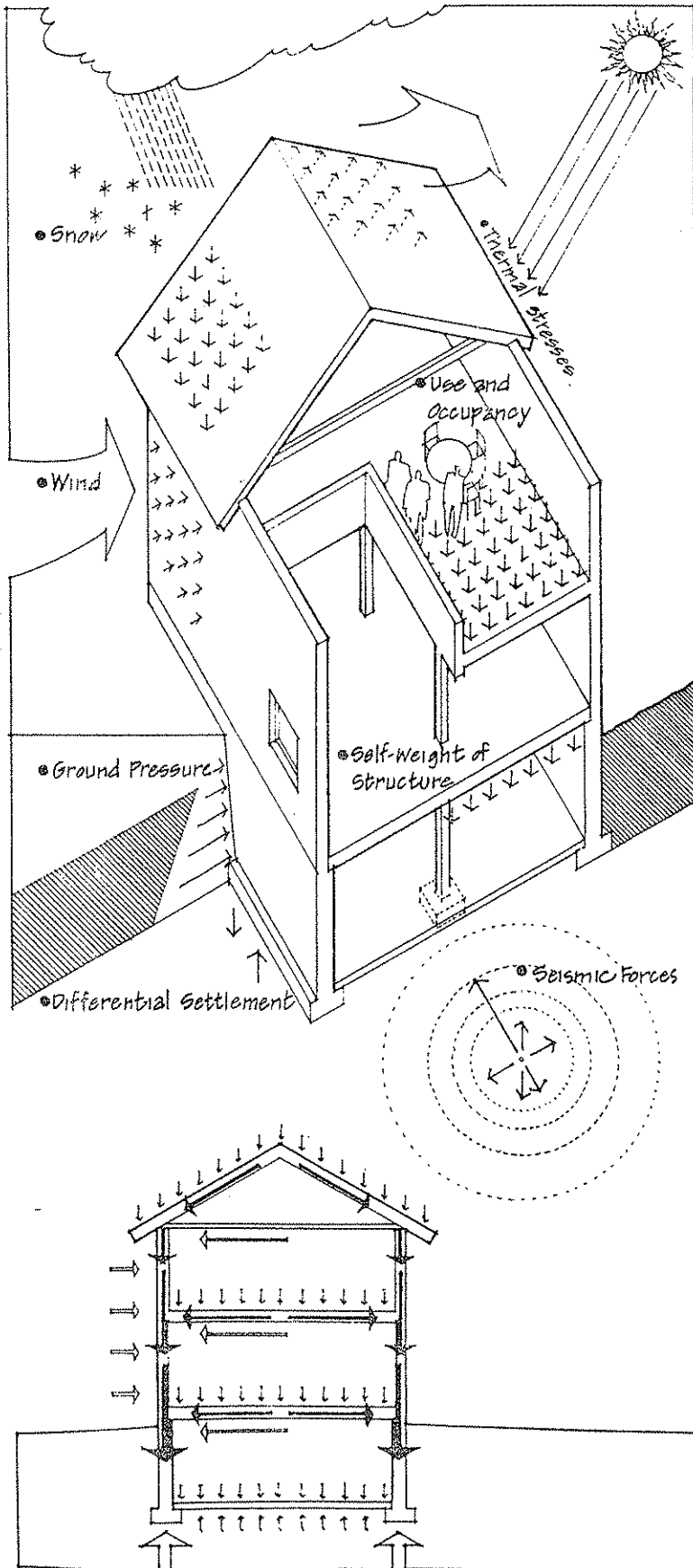
Foundation Systems
Chapter 3

The Building Site
Chapter 1

Notes on Materials
Chapter 12



2.10 LOADS ON BUILDINGS



In enclosing space for habitation, a building's structure must be able to support two types of loads—static and dynamic.

STATIC LOADS are assumed to be constant in nature and are of two kinds:

- Dead loads are relatively fixed and include the weight of the building structure itself as well as the weights of any permanent elements within the building, such as mechanical equipment.
- Live loads are movable loads which may not be present all of the time. They include the weights of a building's occupants and furnishings, as well as snow loads on roofs.

DYNAMIC LOADS can be applied to a structure suddenly and vary in magnitude and location.

- Wind loads can produce pressure or suction on a building's walls and roof planes, depending on their geometry and orientation. The dynamic effects of wind on tall buildings are especially important.
- Seismic forces result from sudden movements in the earth's crust. They are multidirectional in nature and propagated in the form of waves. These cause the earth's surface and any buildings resting on it to vibrate because of the tendency of a building's mass to remain at rest.

While a building's dead loads are relatively fixed in character, static live and dynamic wind and seismic loads can vary in magnitude, duration, and point of application. A building's structure must nevertheless be designed for these possibilities. Building codes typically provide equivalent distributed or concentrated loads for design purposes. These are based on the net effect of the maximum expected combination of forces. (See Appendix for weights of common building materials and typical occupancy and environmental loads.)

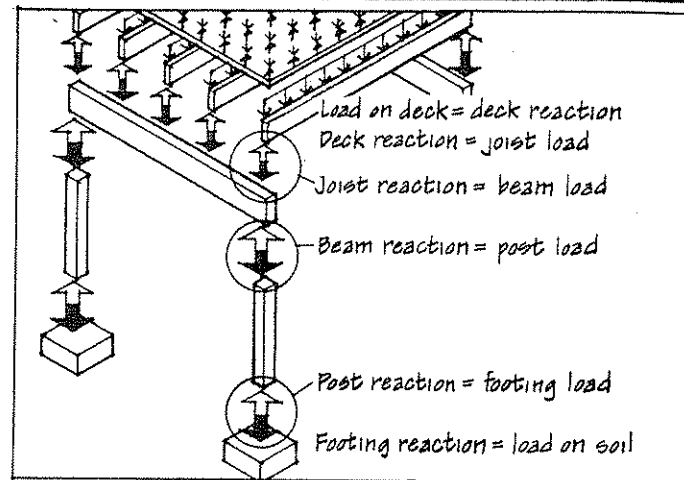
The following is a brief introduction to the way a structural system must resolve the forces acting on a building and channel them to the ground. For more complete information on the structural analysis of buildings, see Bibliography.

STRUCTURAL FORCES

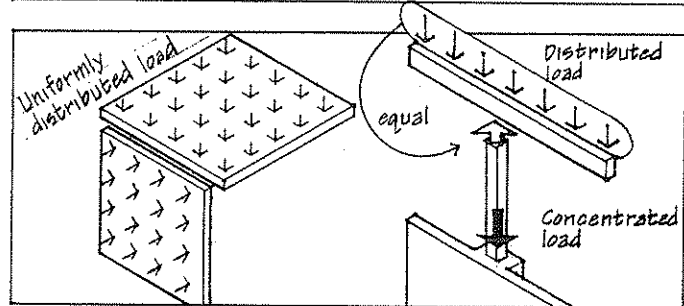
In the structural analysis of buildings, we are concerned with the magnitude, direction, and point of application of forces, and their resolution to produce a state of equilibrium. Three conditions are necessary for a structural system to be in equilibrium:

1. The sum (Σ) of all vertical forces = 0
2. Σ of all horizontal forces = 0
3. Σ of all moments of all forces about any point = 0.

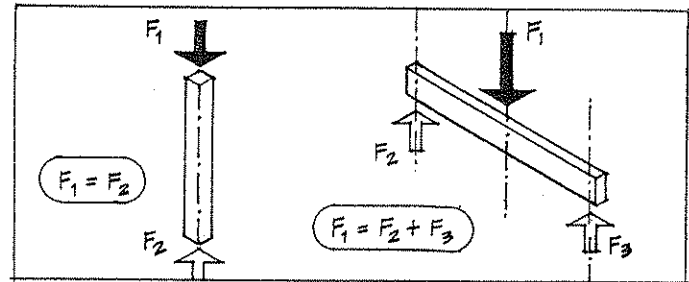
Therefore, as each structural element is loaded, its supporting elements must react with equal but opposite forces.



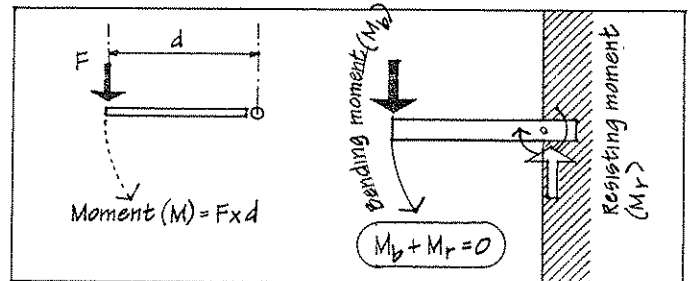
Forces can be assumed to be applied in a uniformly distributed manner, as in the case of a live load on a floor or a wind load on a wall. A force can also be a concentrated load, as when a beam bears on a post or a column bears on its footing.



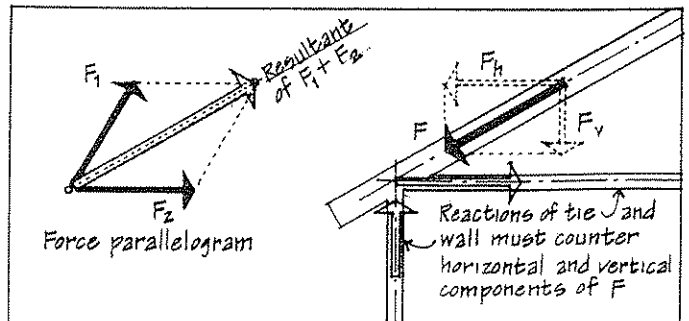
Forces may be parallel and colinear, as when a column supports a vertical load from above. They can also be parallel but not meet, as when a beam supports a load at its midspan. These parallel, nonconcurrent forces will tend to cause a rigid structural element to bend and deflect, which must be resisted by the material's internal strength.



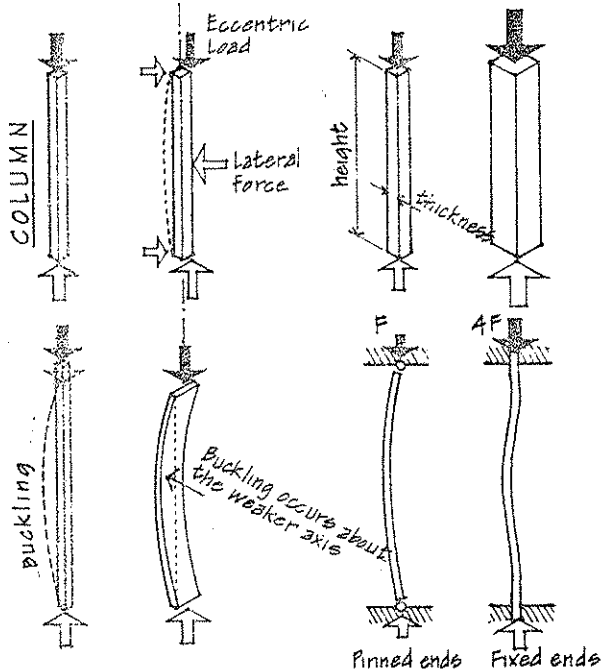
Any force will tend to cause a body to move in the direction of its line of action. The force can also cause the body to rotate if it does not pass through the body's center of gravity. This rotational effect of a force is called a moment. For each moment created by the forces acting on a structural element there must be an equal but opposite resisting moment.



A number of concurrent forces, acting through a common point, can be resolved into a single resultant which is equivalent to the several forces. In a similar manner, an inclined force can be resolved into vertical and horizontal components.



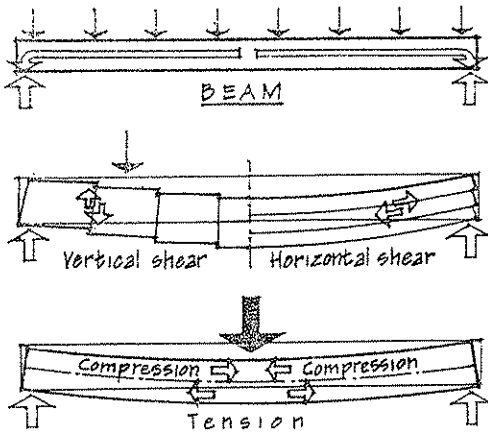
2.12 BASIC STRUCTURAL ELEMENTS



Structural elements can be classified according to their geometry, rigidity, and how they respond to the forces applied to them. External loads create internal stresses within structural elements.

The two basic types of rigid, linear structural elements are the column and beam. A column transmits compressive forces vertically along its shaft. If the load is centered, the column will simply compress. If, however, the load is off center or applied laterally, the column will experience curvature.

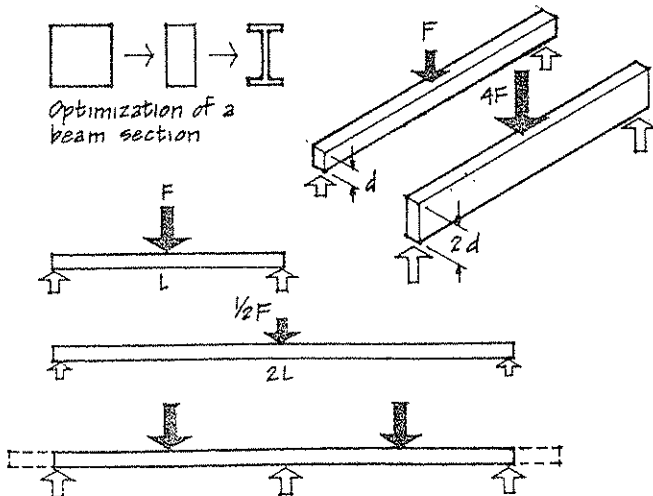
The load carrying capacity of a column varies inversely with its length. The thicker a column is relative to its height, the more it can carry and the better it will withstand eccentric or lateral loading. This height-to-thickness ratio is known as a column's slenderness ratio. Tall, slender columns are especially susceptible to buckling.



A beam transfers its load laterally along its length to its supports. Due to the nonconcurrent pattern of forces, a beam is subject to bending. This results in a combination of compressive and tensile stresses which are greatest along the beam's top and bottom edges. In bending, a beam also becomes subject to horizontal and vertical shear stresses.

As a general rule, the strength of a beam will increase according to the square of its increase in depth, while its stiffness will increase according to the cube of its increase in depth. Similarly, if a beam's length is doubled, the bending stress will double and it will be able to carry only half of its original load. Its deflection under loading will also increase according to the cube of its increase in length.

Cantilevering a beam beyond its end supports can reduce its maximum internal bending moment. Spanning a beam continuously over three or more supports can also reduce the design moment and make the structure more rigid.



A truss consists of short, straight, rigid members assembled into a triangulated pattern. This triangulation is what makes a truss a rigid structural unit. While a truss as a whole is subject to bending, the individual members are subject only to compression or tension.

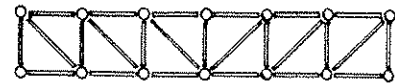
When a beam is supported by two columns, the assembly defines an invisible plane and qualifies the space around it. The typical column-and-beam assembly is not capable of resisting lateral forces unless it is braced. If the joints between the columns and beam are made rigid, then the assembly is called a frame. A rigid frame has a greater measure of lateral stability in the direction of its plane and both columns and beam are subject to bending.

If we fill in the plane defined by two columns and a beam, it acts as a long, thin column in transmitting compressive forces to the ground. This wall, if constructed of reinforced concrete, is capable of resisting lateral forces. If of unit masonry, however, the bearing wall is capable of carrying only in-plane loads. Stresses in a bearing wall have to flow around any door and window openings within the plane.

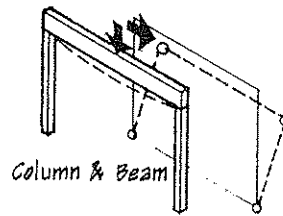
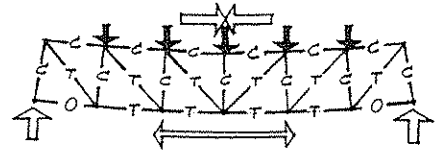
A planar structural element, such as a reinforced concrete slab, can span horizontally and transfer its loads to its supports by bending. A one-way slab acts as a wide, flat beam spanning between two supports. A two-way slab, supported along four sides, is more versatile since it provides more paths along which stresses may travel to the supporting elements.

Long, narrow planar elements can be joined along their edges to form folded plates. These act as beams but are capable of spanning fairly long distances.

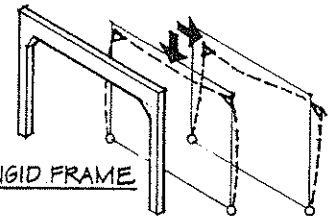
Also capable of long spans is the space frame. While it acts as a planar structural unit, it consists of short, rigid linear members assembled into a three-dimensional triangulated pattern.



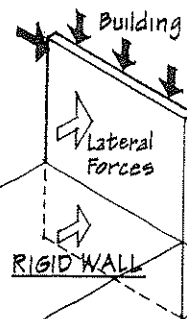
TRUSS



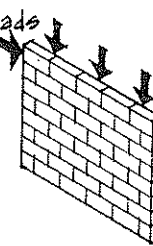
Column & Beam



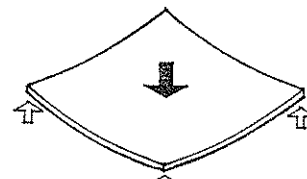
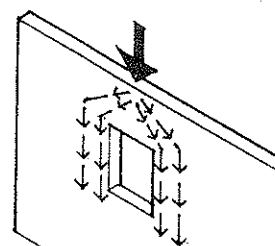
RIGID FRAME



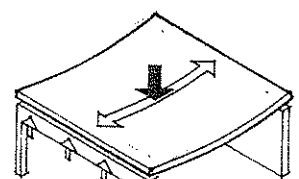
RIGID WALL



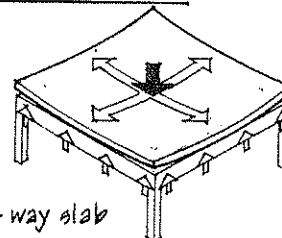
Unit masonry bearing wall



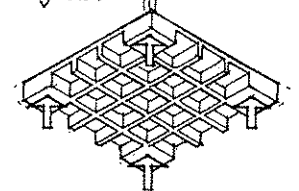
RIGID FLAT PLATE



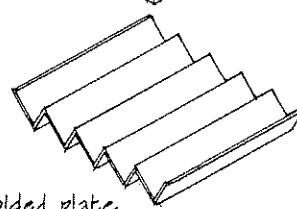
1. way slab



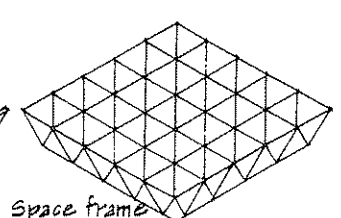
2-way slab



2-way waffle slab

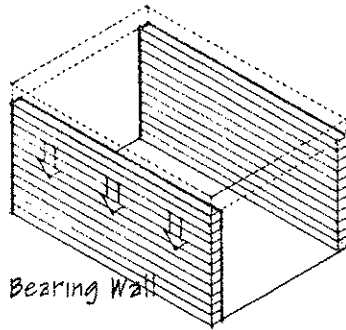
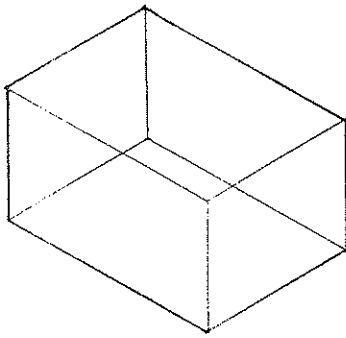


Folded plate

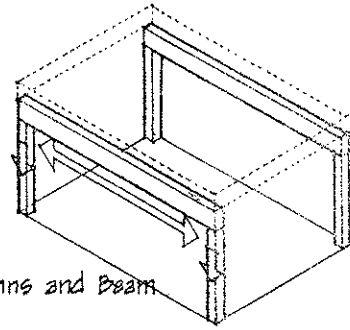


Space frame

2.14 BASIC STRUCTURAL UNITS



Bearing Wall



Columns and Beam

VERTICAL SUPPORTS

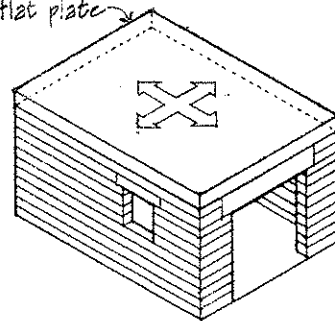
With the primary structural elements of column, beam, slab, and load-bearing wall, it is possible to form a basic structural unit capable of defining and enclosing a volume of space for habitation. This structural unit, whether used alone or in a repetitive manner, is the basic building block for a building's structural system.

On these two pages are described basic types of structural units. The vertical supports may be load-bearing walls, a framework of columns and beams, or simply columns supporting a two-way reinforced concrete flat plate.

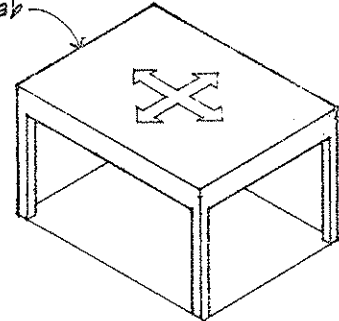
The horizontal spanning element can be a one- or two-way rigid plate of reinforced concrete. An alternative system consists of a hierarchical arrangement of decking supported by one-way joists, beams, and girders.

Linear columns and beams form a three-dimensional skeletal framework with a potential for openness. Load-bearing walls supporting a one-way slab form a planar system which imparts a directional quality to the space defined. Horizontal slabs supported by columns free up the location of walls and define horizontal layers of space.

Reinforced concrete flat plate

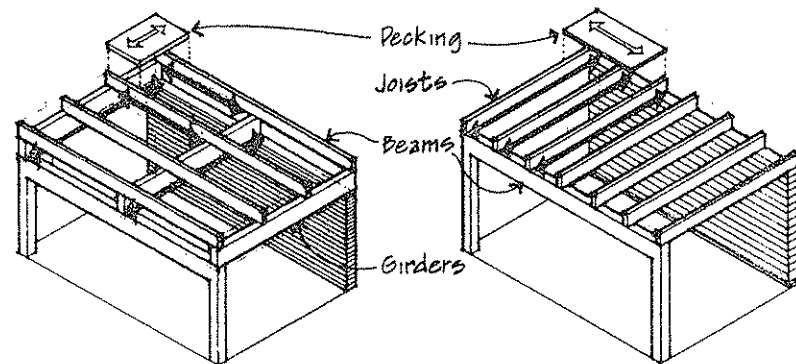
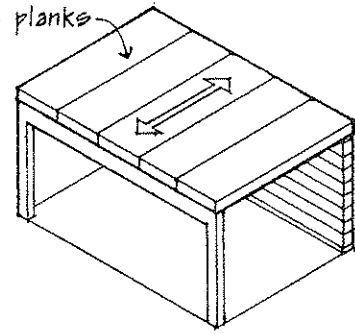
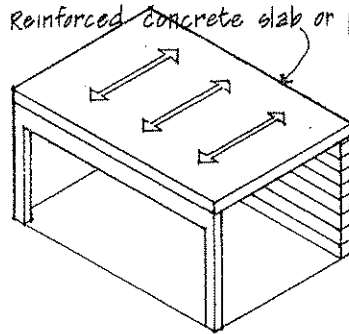


Reinforced concrete 2-way beam and slab

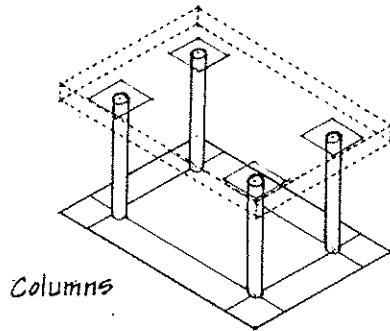


2-WAY HORIZONTAL SPANNING ELEMENTS

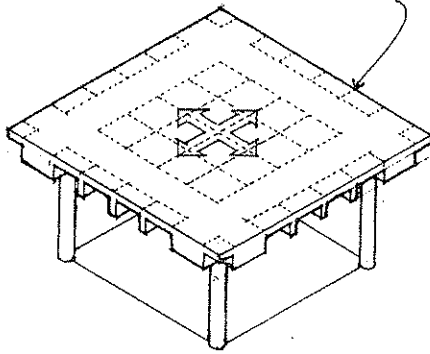
Reinforced concrete slab or precast planks



1-WAY HORIZONTAL SPANNING ELEMENTS



Reinforced concrete waffle slab



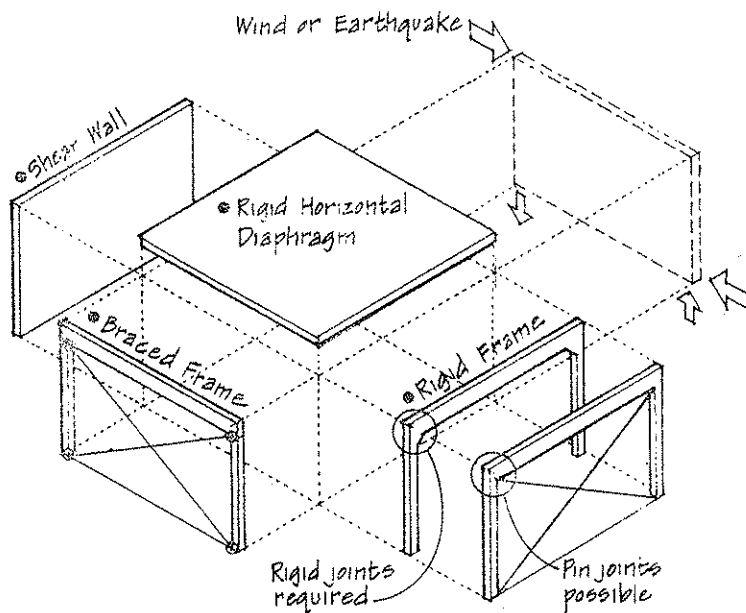
The spanning capability of horizontal elements determines the spacing of their vertical supports. This fundamental relationship between the span and spacing of structural elements influences the dimensions and scale of the spaces defined by a building's structural system. The dimensions and proportion of the system's structural units, in turn, should be related to the programmatic requirements of the building's spaces.

A fundamental distinction between one-way and two-way spanning systems lies in the proportion of the structural bay each can efficiently span. One-way systems are generally preferred when the structural bay is rectangular—i.e., the ratio of the long to the short dimensions is greater than 1.5—or when the structural grid forms a linear pattern. Two-way systems, on the other hand, are more effective for square bays or when the structural grid extends equally in two directions.

Representative SPAN RANGES of different systems in feet		10	20	30	40	50	60	70	80	90	100
1° WAY SPANNING SYSTEMS	Timber	Planks									
		Joists									
		Laminated Beams									
		Trusses									
	Steel	Decking									
		Wide-flange Beams									
		Open-web trusses									
	Reinforced Concrete	Slabs									
		Pan Joists									
		Precast Planks									
		Precast Tees									
		Flat Plate									
		2° way Beam and Slab									
		Waffle Slab									

2.16

LATERAL STABILITY

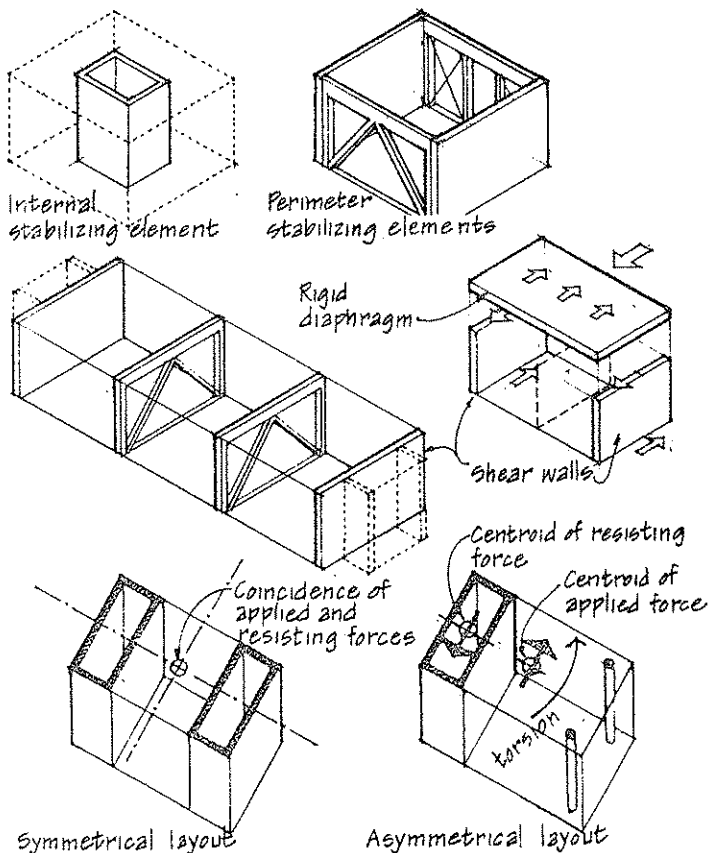


Stabilizing elements are required to resist lateral forces in all directions.

A building's structural elements must be configured to form a stable structure under any possible load conditions. Therefore, while a structural system is designed primarily to carry vertical gravity loads, it must also be able to withstand lateral wind or earthquake forces. There are three basic mechanisms for ensuring lateral stability.

- Diagonal Bracing (timber or steel)
Bracing a frame with diagonal members
- Rigid Frame (steel or reinforced concrete)
Developing a frame with rigid joints capable of resisting changes in angular relationships
- Shear Wall (wood, concrete, or masonry)
Using a rigid planar element capable of resisting shape changes

Any of these systems may be used to stabilize a structure or they may be used in combination. Of the three, a rigid frame tends to be the least efficient. However, rigid frames can be useful when diagonally braced frames or shear walls form barriers which cause functional problems.



Lateral stabilizing elements may be placed within a building or along its perimeter, and combined in various ways. In all cases, however, a number of stabilizing elements must be used to resist lateral forces in all directions.

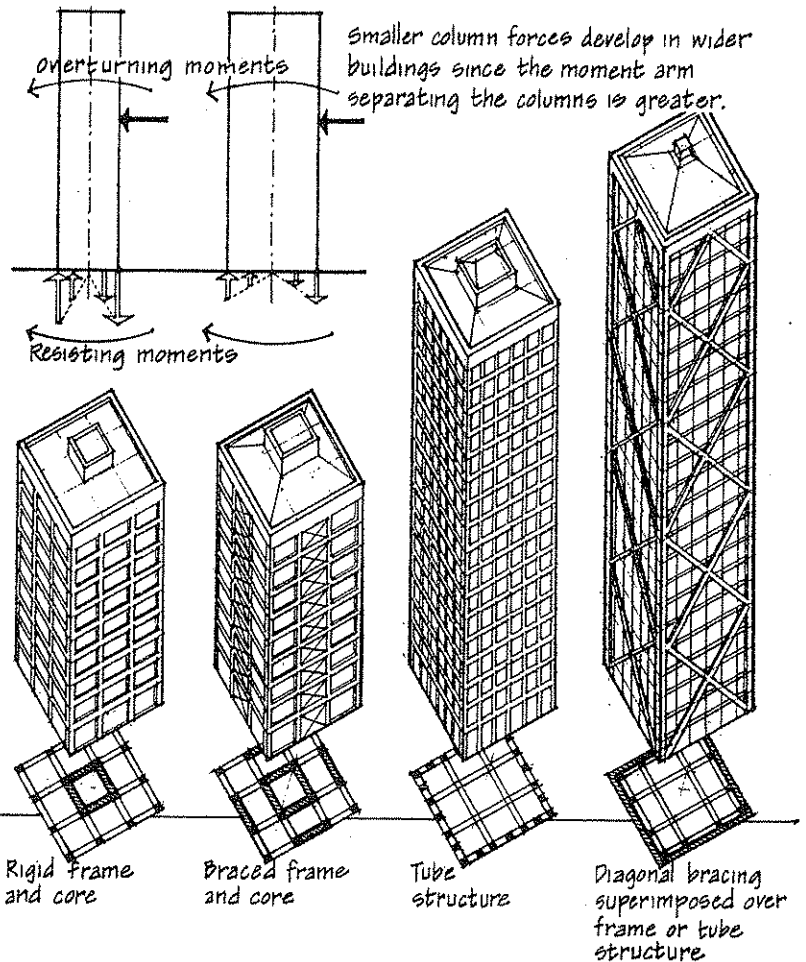
Rigid horizontal diaphragms, acting as flat, deep beams, span between shear walls. These are necessary to transfer lateral loads from non-load-bearing walls to the load-carrying shear walls.

Lateral loads tend to be more critical in the short direction of rectangular buildings and the more efficient mechanisms (shear walls or braced frames) are used in this direction. In the long direction, either similar elements or a rigid frame can be used.

The arrangement of lateral stabilizing elements is important to the stability of a structure as a whole. An asymmetrical layout, where the centroid of the applied force is not coincident with the centroid of the resisting mass, can cause torsional effects. A symmetrical arrangement of lateral stabilizing element is therefore always desirable. This principle is especially important for tall buildings.

Tall buildings are particularly susceptible to the effects of lateral loads. Under lateral loading, they can be seen to act as vertical cantilevers. The overturning moment must be countered by the internal resisting moment of the structure. The wider a tall building is, the greater is its resistance to bending.

A rigid frame is the least efficient way to achieve lateral stability and is appropriate only for low- to medium-rise structures. As the height of a building increases, it becomes necessary to supplement a rigid frame with additional bracing mechanisms, such as a rigid core or diagonal bracing. A stiffer tube structure capable of resisting all lateral forces can be developed by using closely spaced columns rigidly connected to horizontal spandrel beams. For extremely tall structures, major diagonal bracing elements can be superimposed over a rigid frame or tube structure.

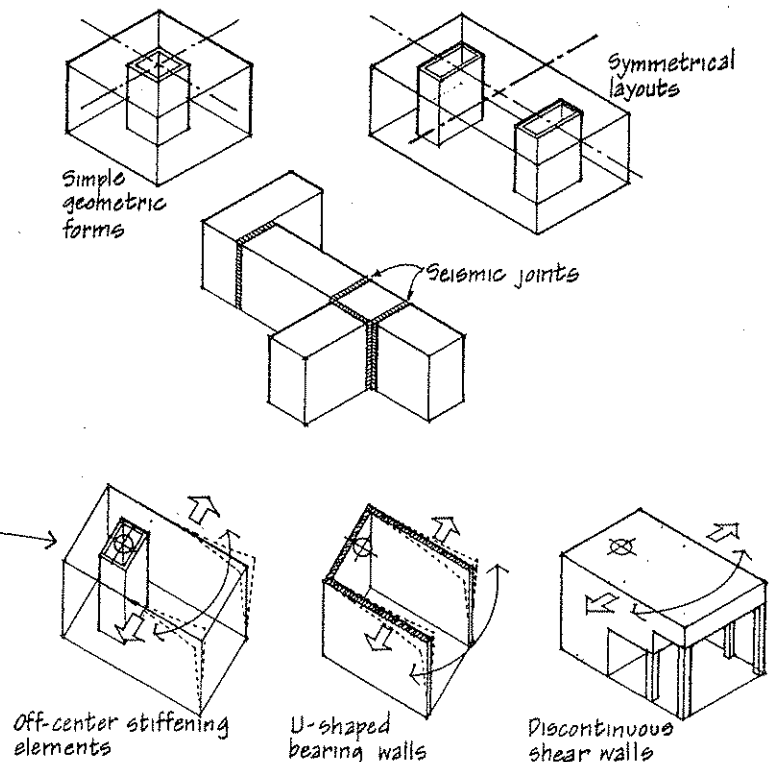


Earthquakes can produce dynamic and complex movements of the ground on which a building rests. While these motions are three-dimensional in nature, from a structural design viewpoint, horizontal ground movements are the most important. Seismic forces are therefore considered to be primarily lateral in character.

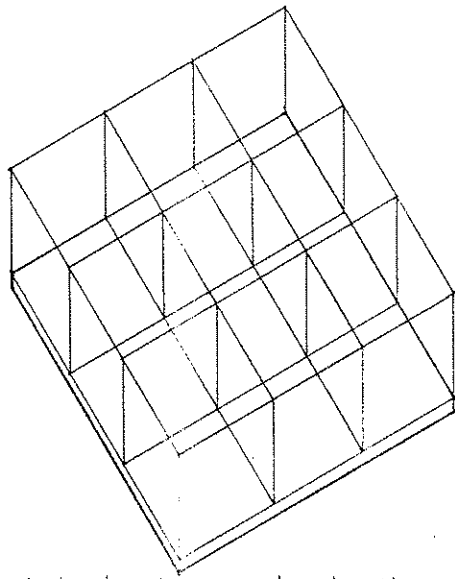
When designing for seismic loads, it is always desirable to use simple geometric forms with a symmetrical layout of building mass, load distribution, and lateral stabilizing elements.

Linear L, T, and H plan shapes should be broken into shorter segments with seismic joints. These allow adjacent sections of a building to move freely and independently of each other.

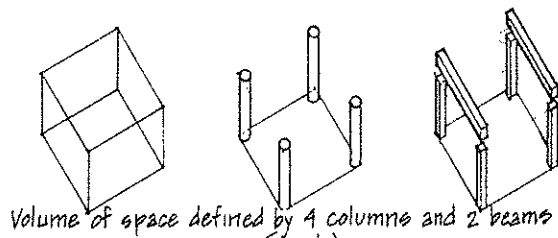
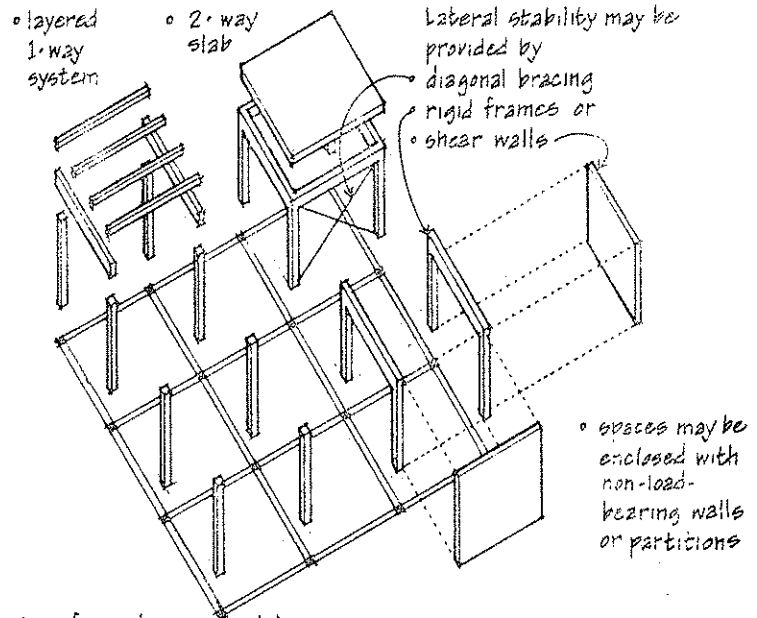
In resisting seismic and other lateral forces, asymmetrical layouts such as these can result in undesirable torsional effects.



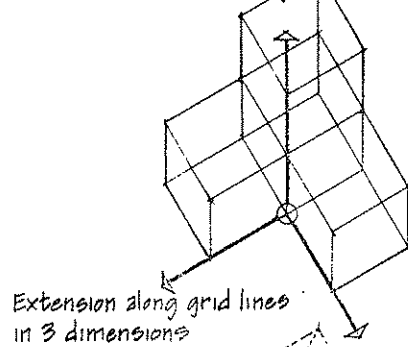
2.18 LINEAR STRUCTURAL SYSTEMS



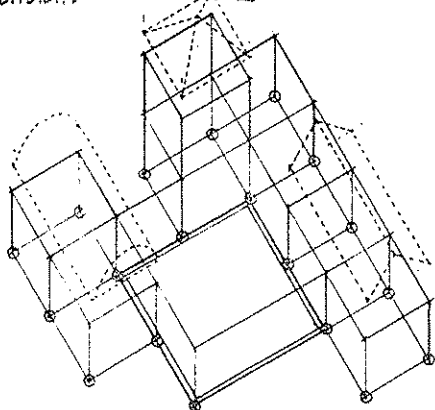
- Idealized 3-dimensional grid as the organizing system for columns and beams



Volume of space defined by 4 columns and 2 beams



Extension along grid lines in 3 dimensions

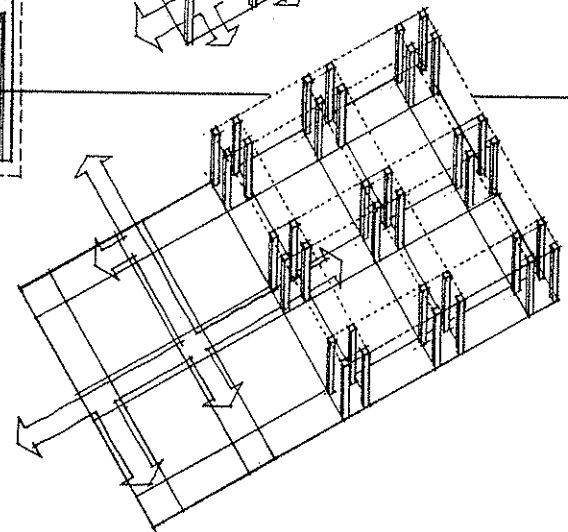
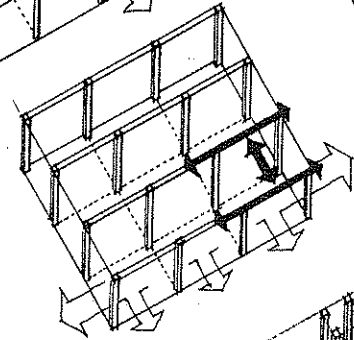
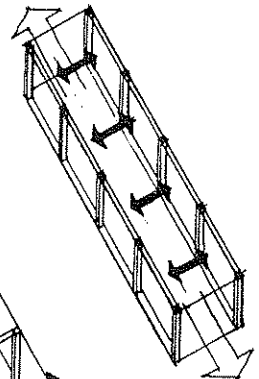
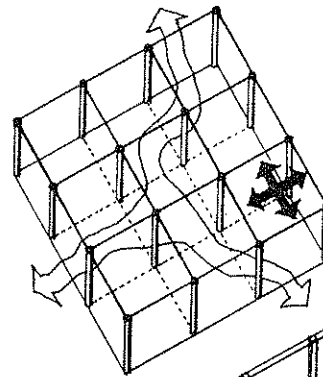
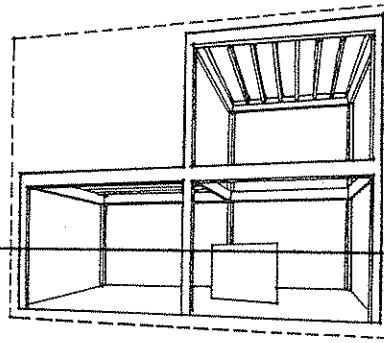
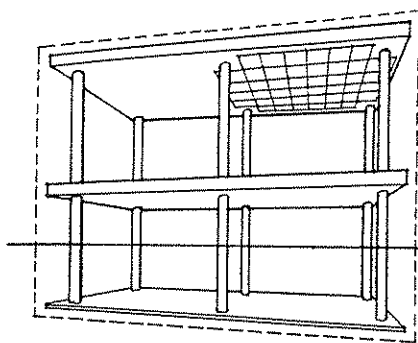


The primary linear structural elements—columns and beams—form a skeletal type of structural system. In plan, the critical points of this linear framework are those at which building loads are carried vertically to the ground along column lines. This gives rise to the use of a grid where the grid lines represent the horizontal continuity of beams and the intersections of the grid lines represent the locations of columns. The inherent geometric order of a grid can be used in the design process to initiate and reinforce a building's functional and spatial organization.

To the left are diagrams which illustrate how a single module of space is defined by four columns supporting two beams. This basic building block can logically be extended vertically along column lines and horizontally along beam lines to form a variety of building shapes. The basic grid can also be altered to accommodate special needs such as large spaces or unusual site conditions.

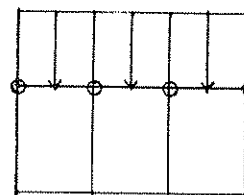
The use of a regular column grid implies the development of a series of repetitive spaces. However, since the walls necessary for the enclosure of interior spaces need not be load-bearing, they can be freely manipulated to define a variety of spatial configurations.

There should be a functional fit between the vertical support pattern of a structural system and the spatial and functional organization of a building. The dimensions and proportions of a structural grid also tell us something about the type of system used to span horizontally between column supports. Two-way systems can efficiently span square bays while one-way systems are generally preferred when spanning linear and rectangular grids. If exposed to view, the directional quality of the horizontal system transfers itself to the interior spaces being spanned.

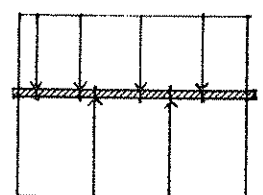


A double grid can be offset to develop interstitial spaces. These intervening spaces can be used to define patterns of movement, mediate between a series of larger spaces, or to house mechanical services.

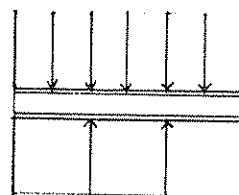
Non-uniform or irregular grids can be used to reflect the functional or hierarchical ordering of a building's spaces. It is also possible to combine different grid patterns in a single structure. One pattern can be a subset of a larger pattern and be related at column locations. When the two patterns cannot be conveniently aligned, a third element, such as a bearing wall, a mediating space, or a finer-grained spanning system, can be used.



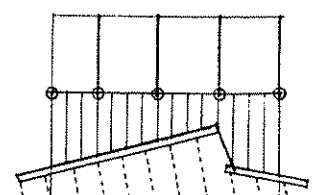
Patterns aligned at column points



Random intersection along a bearing line

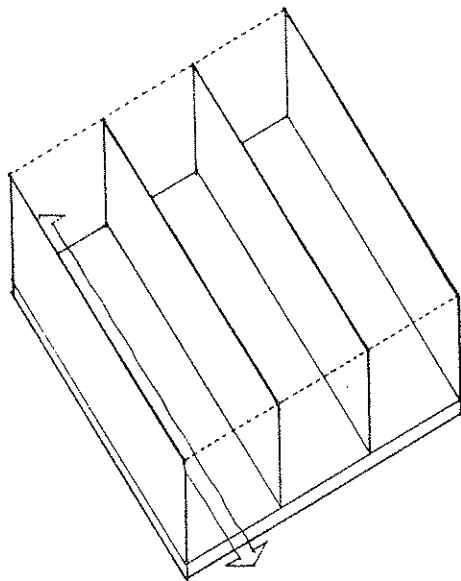


Patterns separated by a mediating space

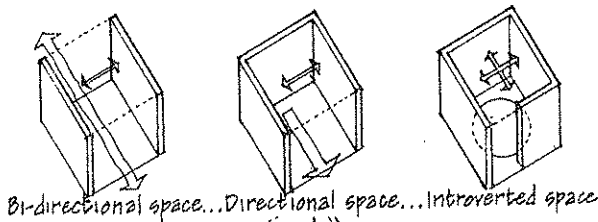
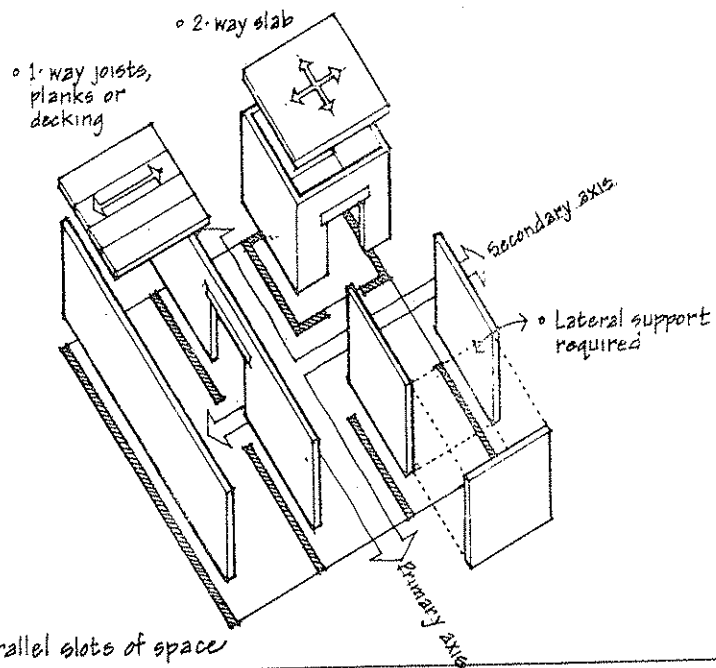


Patterns joined by a third spanning system

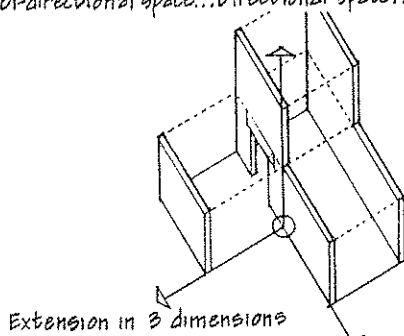
2.20 PLANAR STRUCTURAL SYSTEMS



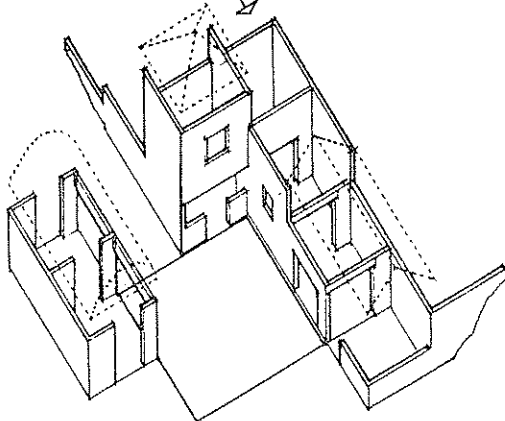
- An idealized load-bearing wall system defines parallel slots of space



Bi-directional space... Directional space... Introverted space



Extension in 3 dimensions



The major planar structural elements are the vertical load-bearing wall and the horizontal slab. These rigid elements can be combined to form a structural system that is capable of enclosing space as well as supporting building loads.

A planar structural system typically consists of a parallel series of load-bearing walls. Two such walls naturally define an axial, bi-directional space. Closing one end with a shear wall results in a space oriented towards the open end. Closing the other end as well creates an introverted space capable of being spanned with a two-way system.

Secondary axes can be developed perpendicular to the primary axis with openings within the load-bearing walls. Care should be taken that these openings do not weaken the wall's integrity, strength, and rigidity.

Load-bearing walls are most effective in resisting forces along their planes, and most vulnerable to forces perpendicular to their planes. The stability of a load-bearing wall system therefore depends on the support of perpendicular shear wall planes as well as the rigidity, stiffness, and mass of the walls themselves.

To the left are diagrams which illustrate the variations in form possible through the manipulation of the length, height, spacing, and orientation of load-bearing walls.

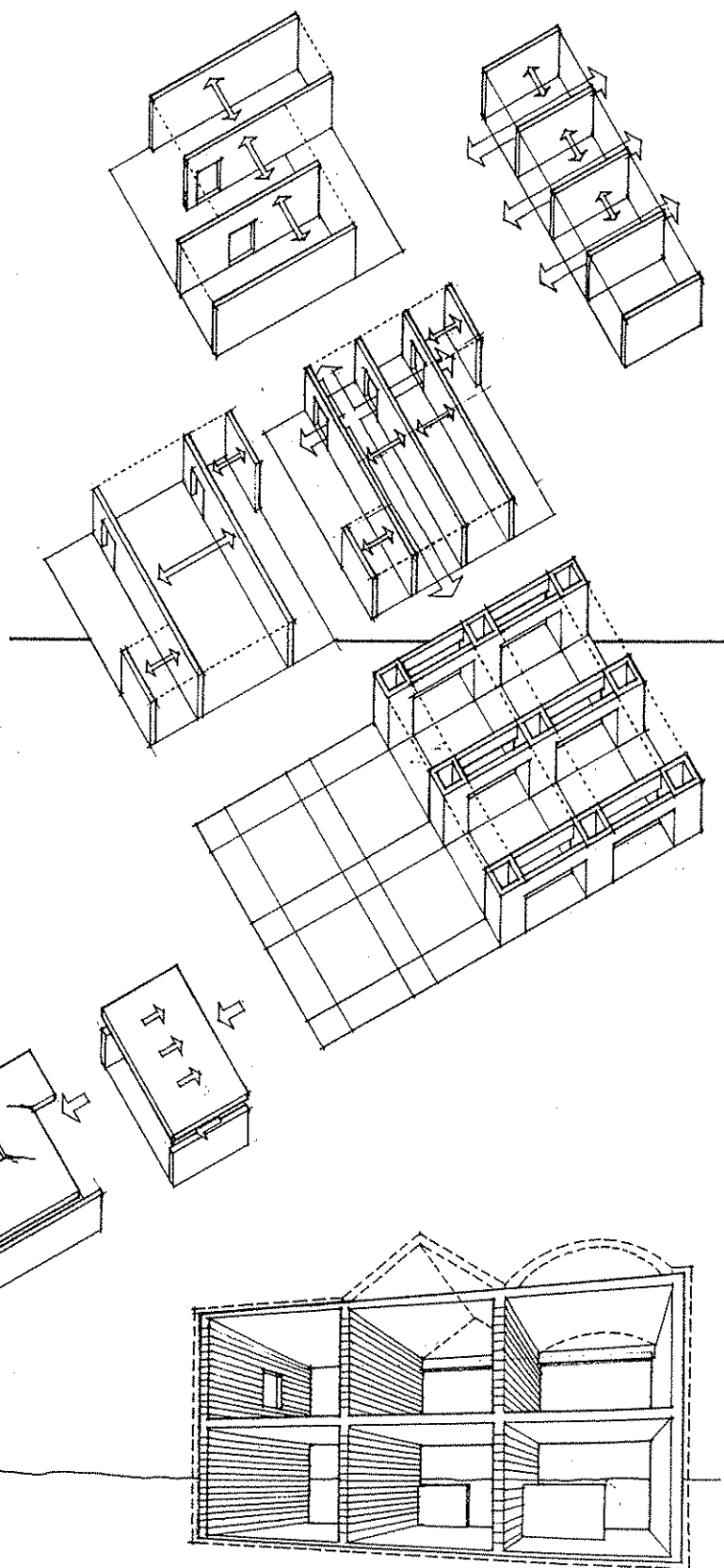
The parallel nature of a load-bearing wall pattern fits well with one-way spanning systems, since load-bearing walls are most effective when carrying distributed loads, they typically support a series of joists, planks, or a one-way slab. Any system using widely spaced beams creates concentrated loads which require reinforcement or thickening at the beam support locations.

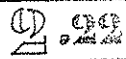
A common plan configuration is a series of load-bearing walls which define and separate a number of repetitive spaces. Openings are possible at either end of the spaces if lateral stability can be achieved with transverse frames or shear walls.

More complex plan configurations are possible since sets of parallel load-bearing walls can be arranged perpendicular to each other. Because of the planar nature of load-bearing walls, there should be a correspondence between their spacing and the functional requirements of the defined spaces. The location and orientation of load-bearing walls, however, should also be determined by the requirements for lateral stability.

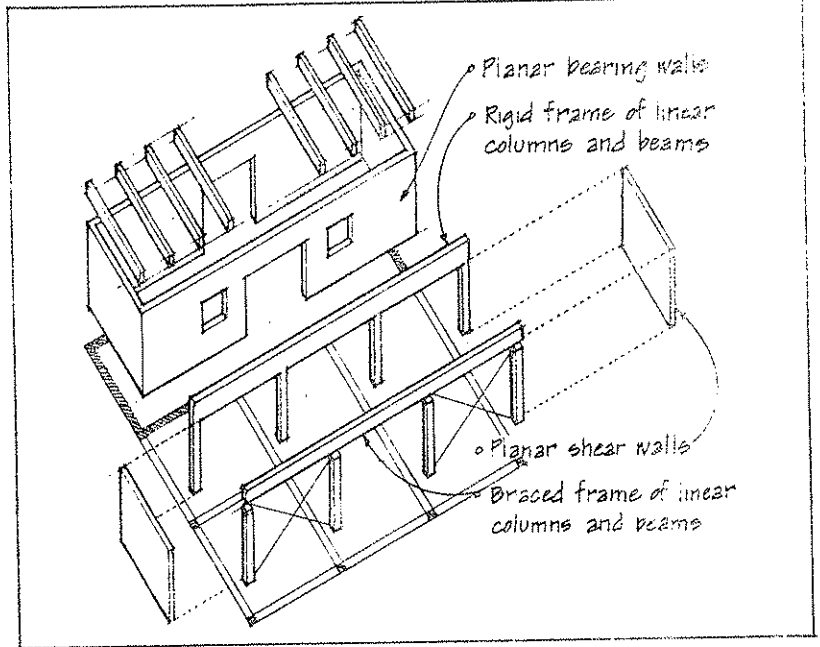
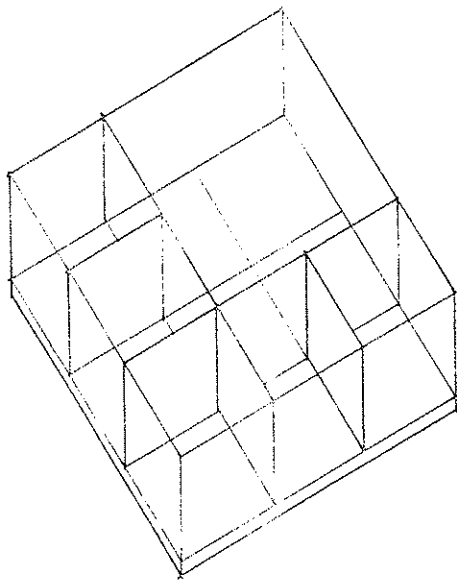
Load-bearing walls may be thick enough that voids within their construction can be used as service spaces. Even double walls organized along a tartan grid can be seen to be similar in nature to thick load-bearing walls.

In order to transfer lateral wind or earthquake forces to load-bearing walls that serve as shear planes, floor planes must be designed as rigid horizontal diaphragms. Since these act as thin, deep beams, they should be carefully designed. Plan shapes not suitable as normal beam shapes should be avoided.





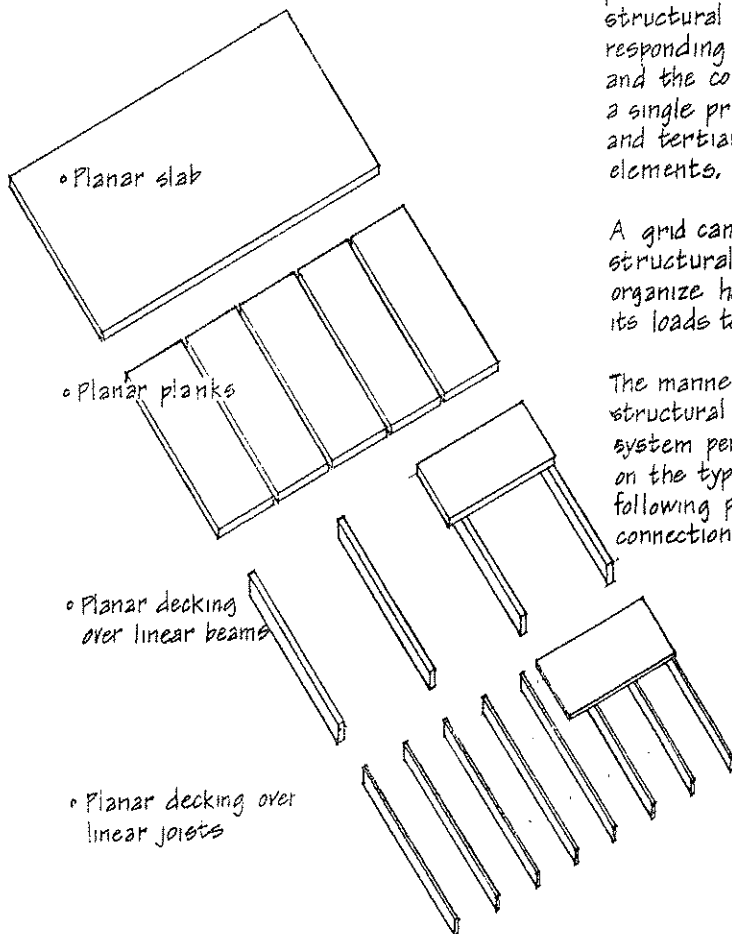
COMPOSITE STRUCTURAL SYSTEMS



Combining both linear and planar structural elements, it is possible to form a composite structural system. Composite structural systems allow a building to be more flexible in responding to the programmatic requirements of its spaces and the context of its site. Even when a building utilizes a single primary type of structural system, the secondary and tertiary systems consist of both linear and planar elements.

A grid can again be used to coordinate a building's structural, spatial, and functional systems, and to organize how the structural system collects and channels its loads to the ground.

The manner in which forces are transferred from one structural element to the next and how a structural system performs as a whole depend to a great extent on the types of joints and connections used. On the following page are described the basic types of connections used in building construction.

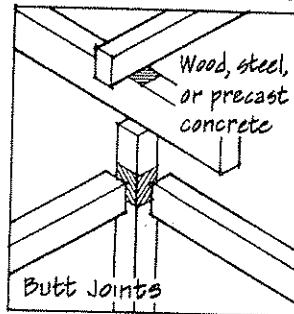


JOINTS AND CONNECTIONS

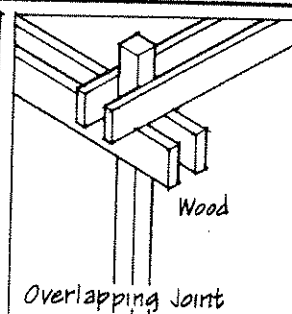
2.23

Structural elements can be joined to each other in three ways. Butt joints allow one of the elements to be continuous and usually require a third mediating element to make the connection. Overlapping joints allow all of the connected elements to bypass each other and be continuous across the joint. The structural elements can also be molded or shaped to form the connection.

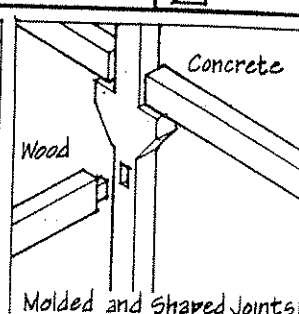
The connectors used to join the structural elements can be in the form of a point, line, or surface. While line and surface types of connectors resist rotation, point connectors do not unless distributed across a large surface area.



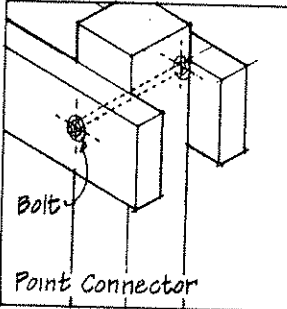
Butt Joints



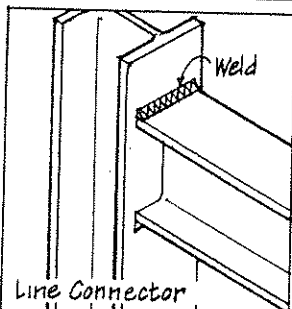
Overlapping Joint



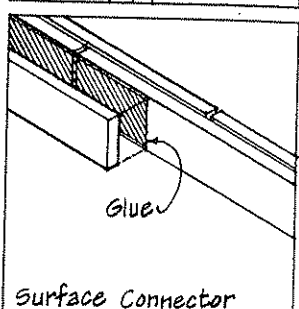
Molded and Shaped Joints



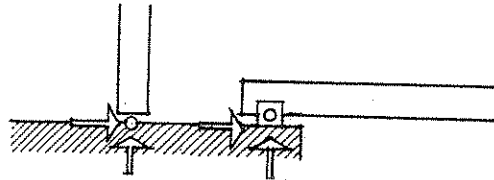
Point Connector



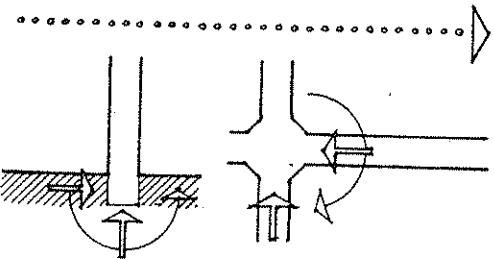
Line Connector



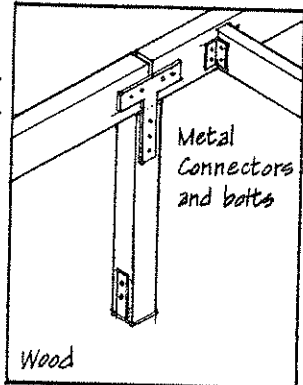
Surface Connector



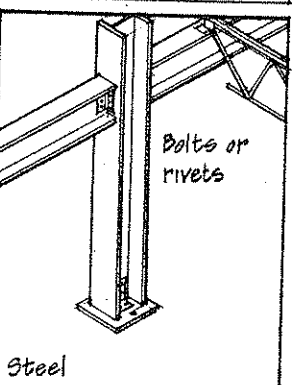
PINNED JOINTS theoretically allow rotation but no translation in any direction.



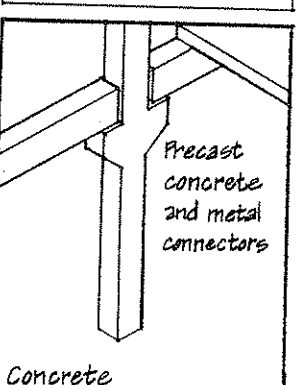
FIXED or RIGID JOINTS resist moments and forces in any direction and therefore do not allow any rotation or translation to occur.



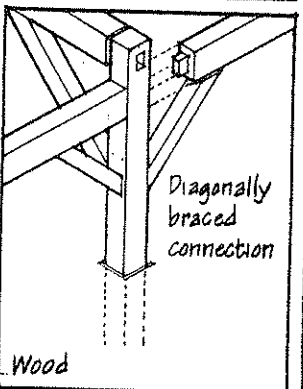
Wood



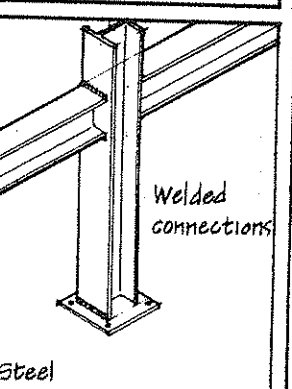
Steel



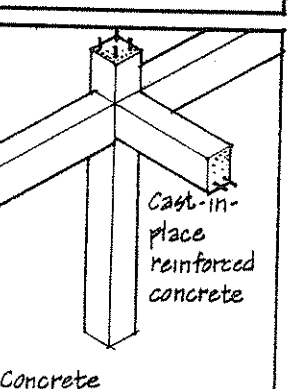
Concrete



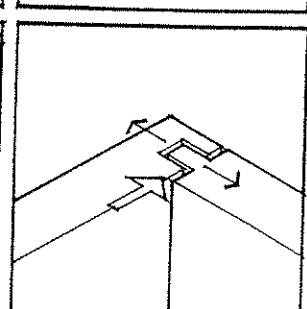
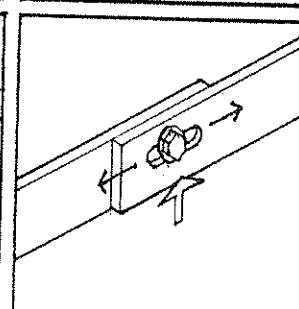
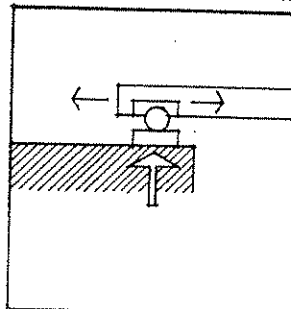
Wood



Steel



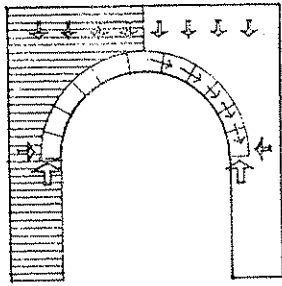
Concrete



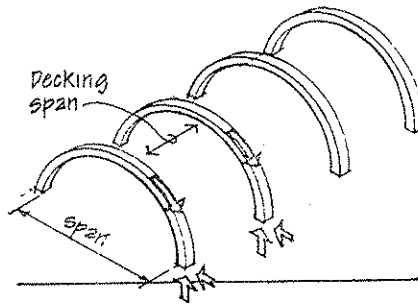
ROLLER JOINTS allow rotation but resist translation in one direction only. They are not as commonly used as pinned or fixed connections but the principle behind roller joints can be seen to apply to joints that allow expansion and contraction of a structural element to occur.

2.24

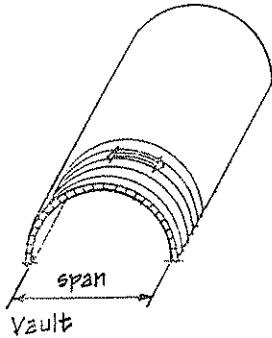
OTHER STRUCTURAL SYSTEMS



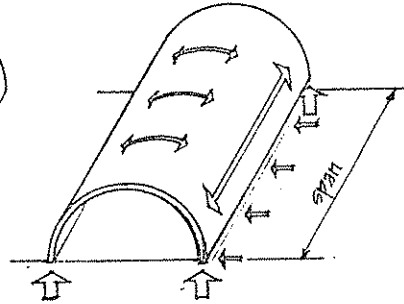
Block Arch



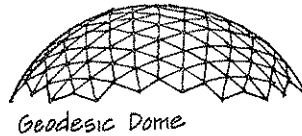
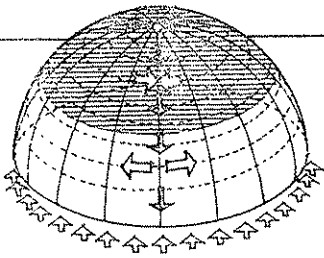
Rigid Arch



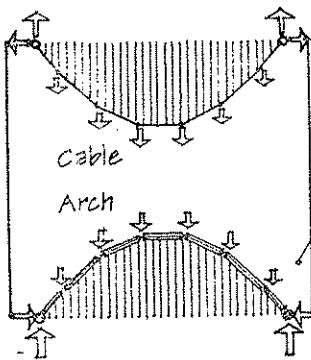
Vault



Barrel Shell

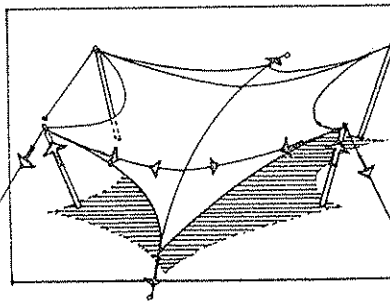


Geodesic Dome

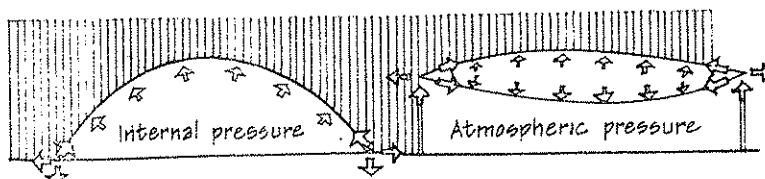


Cable

Arch



Membrane Tent Structure

Pneumatic Structure:
Air-supportedDouble Membrane System:
Air-inflated

Columns, beams, and slabs are the most common structural elements because of the rectilinear building geometry they are capable of generating. There are, however, other means of spanning and enclosing space. These are generally form-active elements which make efficient use of their material for the distances spanned because of their geometry and shape. While beyond the scope of this book, they are briefly described below.

An ARCH is a curved structural element that spans between two points. A block arch is capable of carrying only in-plane forces which cause the segments to compress uniformly. A rigid arch, on the other hand, consists of a continuous piece of a curved rigid material such as steel or concrete.

A VAULT is a singly curved structural plane that spans transversely, like a continuous block arch. A CYLINDRICAL SHELL is similar in form but spans longitudinally like a beam with the curve perpendicular to the span.

A DOME is a spherical surface structure that can be made of stacked blocks, a continuous rigid material like reinforced concrete, or of short, rigid linear elements as in the case of a geodesic dome. A dome is similar to a rotated arch except that circumferential forces are developed which are compressive near the crown and tensile in the lower portion.

CABLES are flexible structural elements which must be used purely in tension. When subject to concentrated loads, a cable's shape consists of straight-line segments. Under a uniformly distributed load, it will take on the shape of an inverted arch. A NET is a three-dimensional surface made up of a series of crossed curved cables.

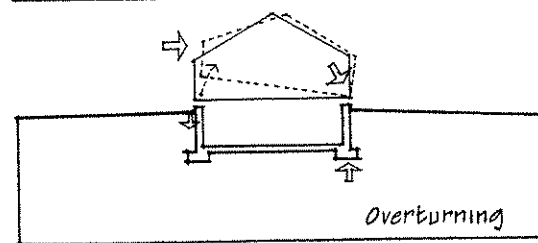
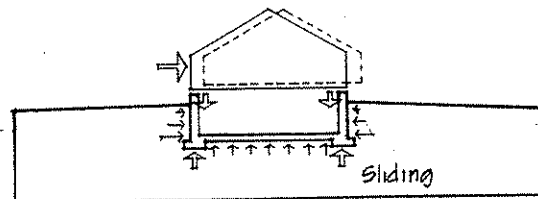
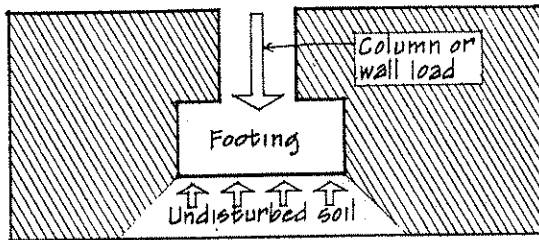
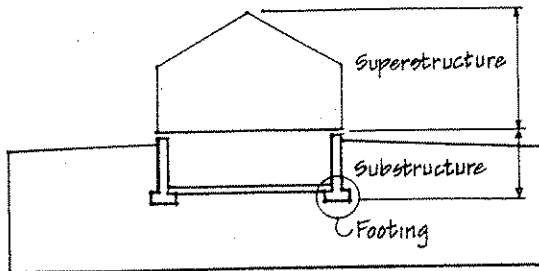
MEMBRANES are also flexible structural elements. The thin sheet material may be suspended or stretched between posts, or be supported by air pressure.

FOUNDATION SYSTEMS

The foundation system for a building—its substructure—is the critical link in the transmission of building loads down to the ground. Bearing directly on the soil, the foundation system must distribute vertical loads so that settlement of a building is either negligible or uniform under all parts of a building. It must also anchor the building's superstructure against uplifting and racking due to wind or earthquake forces. The most critical factor in determining the foundation system of a building is the type and bearing capacity of the soil to which the building loads are distributed.

Foundation systems are presented in three categories according to the geometric analogies of point, line, and plane. Each type of foundation system described in this chapter can support certain wall and floor systems. Just as the type of foundation system used is regulated by the soil and topography of the building site, the choice also affects the potential form of the superstructure.

3.2 FOUNDATION SYSTEMS



The foundation system is that part of a building's substructure which transmits the building's loads down to the supporting soil. These loads include the dead load of the building's weight and the live load of its occupants and contents. A foundation system may also have to resist ground pressure as well as anchor the building's superstructure against uplift or racking due to lateral wind or earthquake forces.

TYPES OF FOUNDATION SYSTEMS

A foundation system typically consists of columns, piers, or walls which rest on footings. These footings are the widened parts of the foundation which rest directly on the soil. They are spread in order to distribute their loads over a wide enough area that the soil's bearing capacity is not exceeded.

Footings should always rest on undisturbed soil. When this is not possible, concrete or a specially engineered and compacted fill should be used to make up the extra depth. Avoid bearing on unstable or organic soils, wet clays, or on ground with poor drainage.

When the soil underlying a foundation system is not adequate to support the building's loads, column-like piles are used to penetrate down to a more suitable bearing stratum of rock or dense sands and gravels. Piles can also be supported by the frictional resistance developed between the pile surfaces and the surrounding soil.

Spread footings are usually of plain or reinforced concrete while piles may be of wood, steel, plain concrete, or reinforced concrete. These basic types of foundation systems are discussed further on 3.4 and 3.5.

FOOTING SIZE

Since footings for residential and other light construction transmit relatively light loads, their size can usually be estimated by the following when they bear on stable soil.

For foundation walls: Width (W) = 2 x thickness of foundation wall
Thickness (T) = thickness of foundation wall

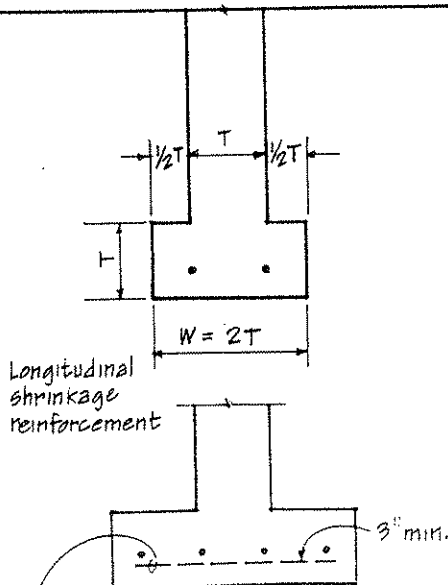
For columns and piers: $A = P/S$, where

A = horizontal bearing surface of footing

P = column load in pounds

S = soil bearing capacity in lbs./s.f.

When bearing on poor soil or designing for heavy loads or sloping sites, soil samples should be tested and an engineering analysis made to determine the type and size of foundation system that is required. Consult a structural engineer.



Steel reinforcement is required when footing projects more than half of foundation wall thickness and becomes subject to bending.

BUILDING SETTLEMENT

As a building bears down on the supporting soil, some settlement is to be expected. A properly designed and constructed foundation system should minimize this settlement or make it negligible. Whatever settlement does occur should be equal under all parts of a building. This is accomplished by laying out and proportioning the foundation supports so that they transmit an equal load per unit area to the soil. Uneven or differential settlement can cause a building to shift out of plumb and cracks to occur in its foundation, structure, or finishes. If extreme, differential settlement can result in the failure of a building's structural integrity.

Settlement is due primarily to a reduction in the volume of voids in the soil. This reduction is slight and occurs rather quickly as loads are applied on dense, granular soils. On clays, settlement can be greater since clay has a relatively large percentage of voids. Consolidation of clay can also be continuous over a long period of time since any water present cannot pass through the clay easily. Though not as common, the lateral displacement of soil in embankments or adjacent to excavations can also cause settlement to occur.

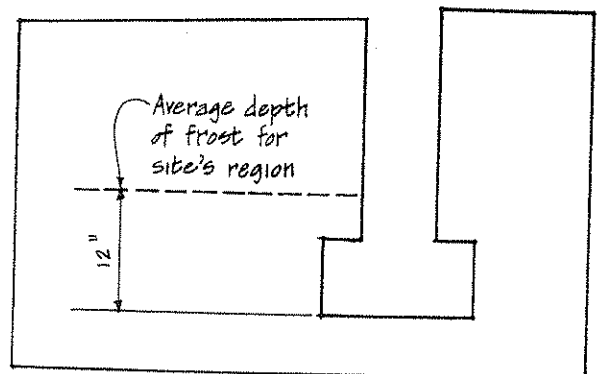
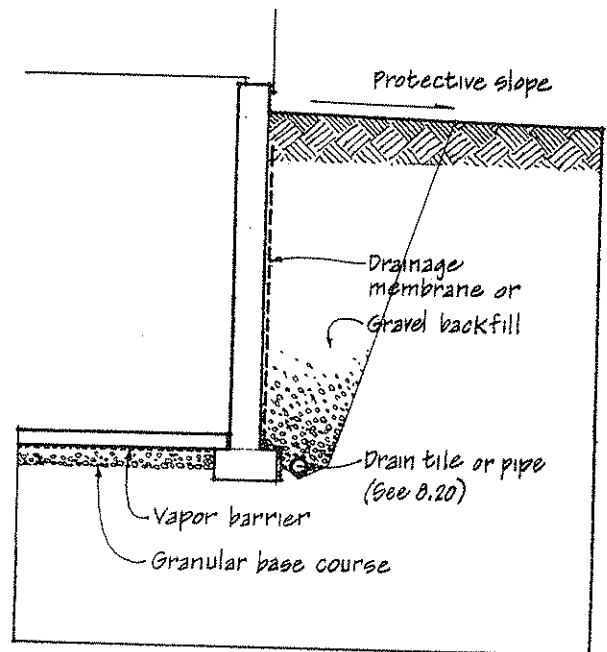
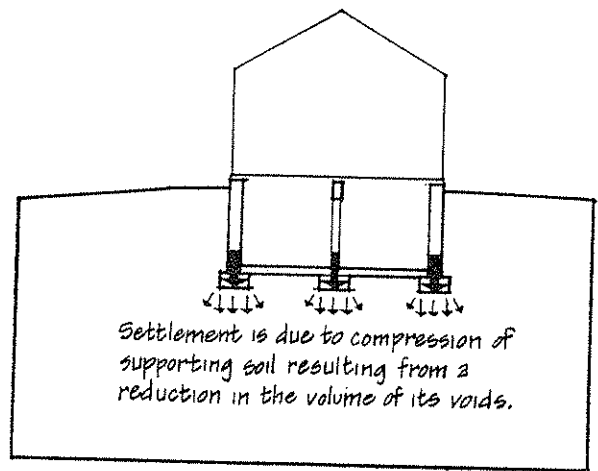
WATER

Ground water can place pressure on and penetrate foundation walls and ground slabs below grade, especially if they lie below a site's water table. Foundation walls enclosing basement spaces should be waterproofed and a perimeter drainage system used to collect and divert water away from the foundation. In cohesive soils, ground water can also rise through capillary action and penetrate a building's ground slab or crawl space. Capillarity can be controlled with a combination of granular base materials and vapor barriers.

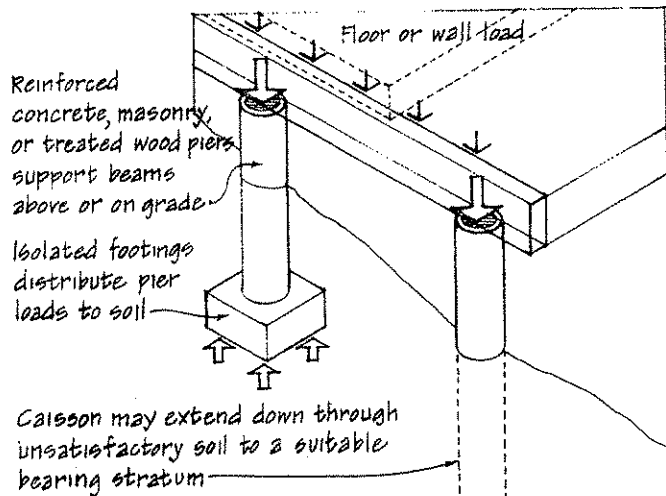
Surface water should be drained away from a building using protective slopes: 3% minimum for grassy or planted areas and 1% for paved surfaces.

FROST

Since water expands upon freezing, ground heaving can occur as soil moisture freezes in cold weather. To minimize the effect of this frost action on a foundation, footings should be placed below the deepest frost penetration expected at the building site. Since this frostline varies from region to region, its depth should be verified when a specific site is selected. In addition, footings should not be placed on frozen ground. As the frozen soil thaws under the pressure of the building load, excess water can cause the soil to lose much of its bearing capacity.

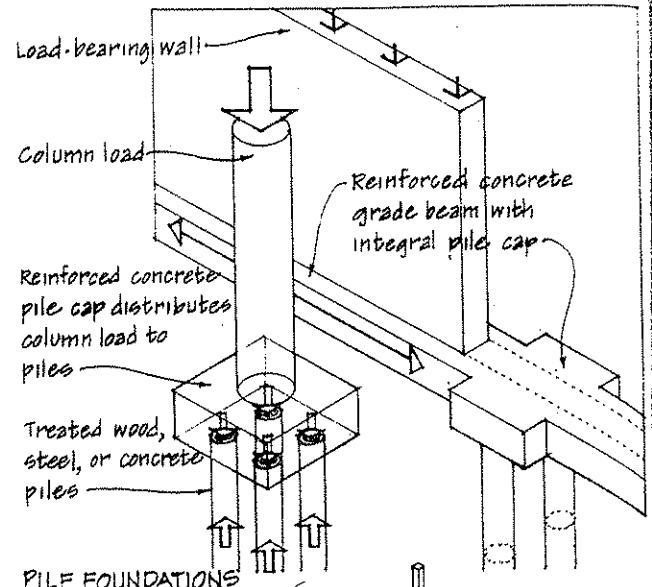
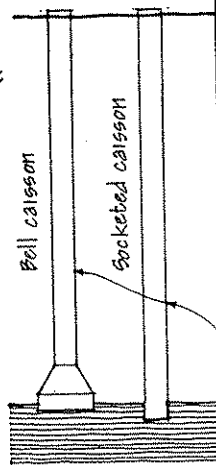


7.4 TYPES OF FOUNDATION SYSTEMS



PIER FOUNDATIONS

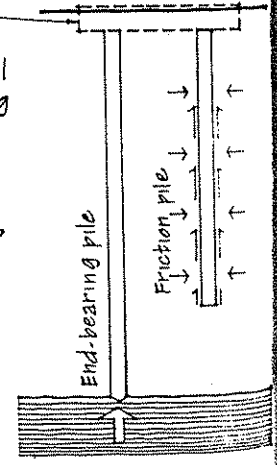
- A grid of isolated piers and footings can be used in residential and light construction to elevate the superstructure above the ground plane.
- Piers can extend up and serve as columns for the superstructure.
- Floor planes elevated above grade should be insulated.
- Piers can also be used to provide point supports for grade beams.
- When carrying heavy loads, pier or column footings can be combined into a strip footing which acts as a continuous beam.
- A combined footing is also used to tie two columns together when one of the columns must abut a property line.

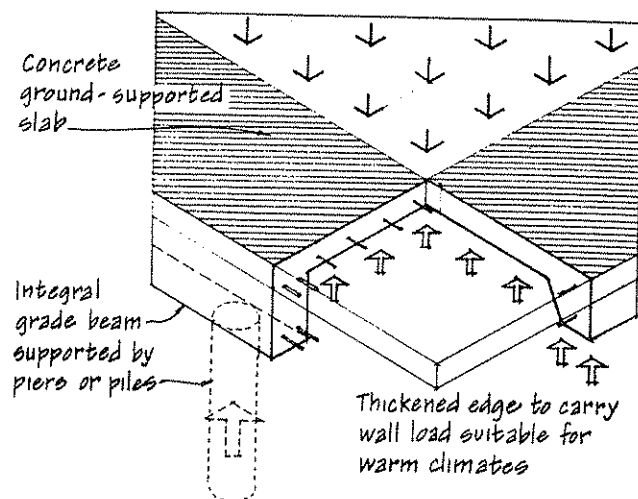
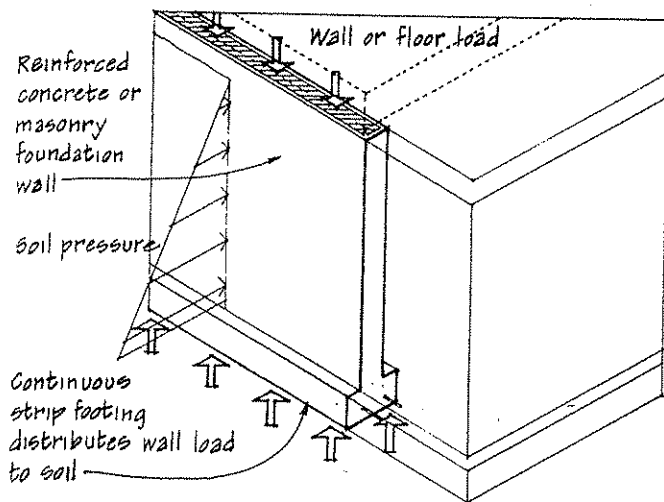


PILE FOUNDATIONS

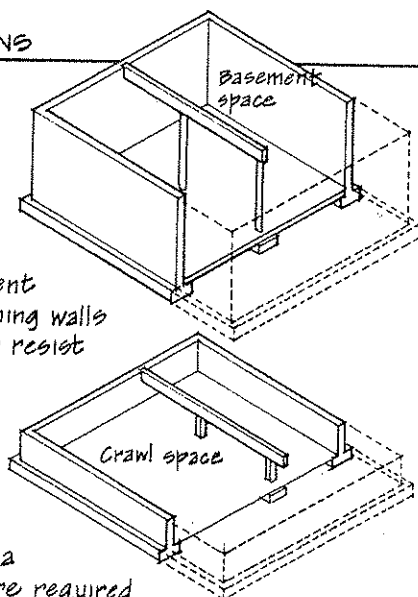
- When large buildings generate loads which exceed the soil's bearing capacity, piles are used to penetrate down to a more suitable bearing stratum.
- Piles are typically driven closely together in clusters, each of which is joined at the top by a reinforced concrete pile cap.
- Piles may be end-bearing or be supported by the frictional resistance of the surrounding soil.
- Piles may be of treated timber, but for large buildings, steel H-sections, concrete filled pipes, or precast reinforced or prestressed concrete are more common.

- Caissons are similar to piles in function but they consist of plain or reinforced concrete which is sitecast into drilled holes.



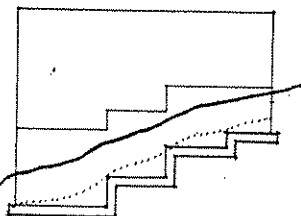


WALL FOUNDATIONS

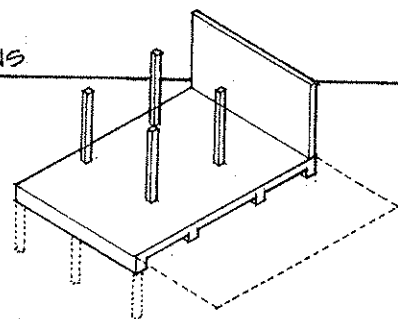
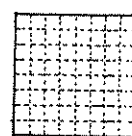


- Foundation walls enclosing a basement space act as retaining walls and must be able to resist soil pressure.
- A rigid floor plane and basement slab can provide lateral support.
- Waterproofing of basement walls and a drain tile system are required where ground water exists
- Basement slabs and crawl spaces require vapor barriers to control passage of ground moisture.
- Crawl spaces also require ventilation.

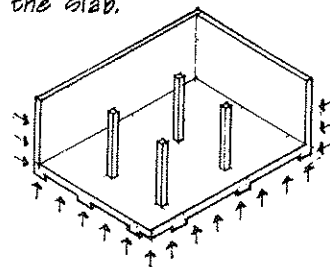
- On sloping sites, stepped footings are necessary to maintain the required footing depth below grade at all points around a building.



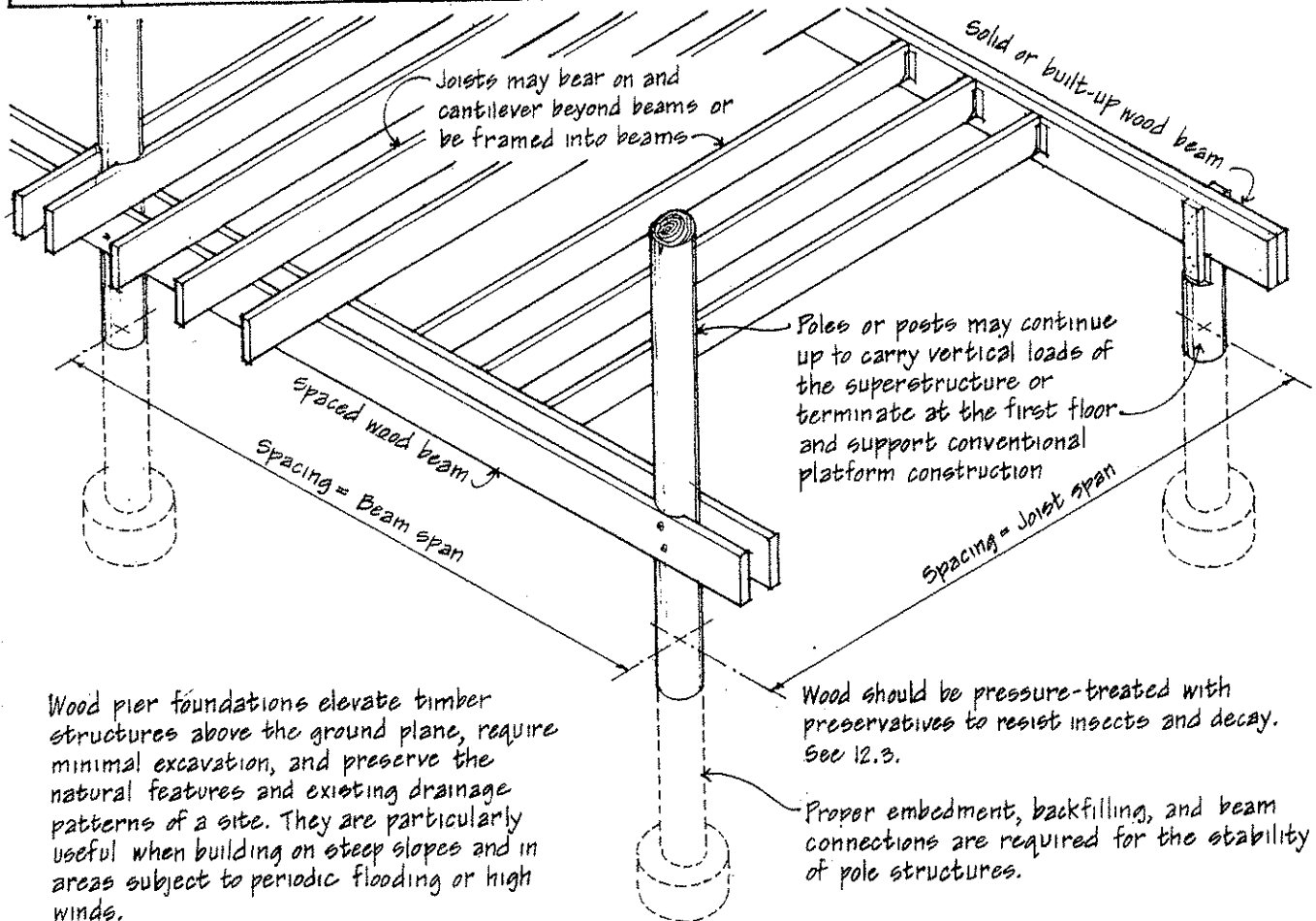
SLAB FOUNDATIONS



- When a concrete ground slab is built independent of a building's foundation, it requires only a stable, compact bed for support.
- In climates where little or no ground frost occurs, a ground-supported slab can be thickened to carry wall and column loads.
- When wide column footings are required so as not to exceed a soil's bearing capacity, it may be more efficient and economical to join them into a mat foundation.
- A mat foundation is a thick, reinforced slab that acts as a single footing for an entire building. It is designed as an integral structural unit with the superstructure capable of transmitting loads to the foundation soil under the entire area of the slab.

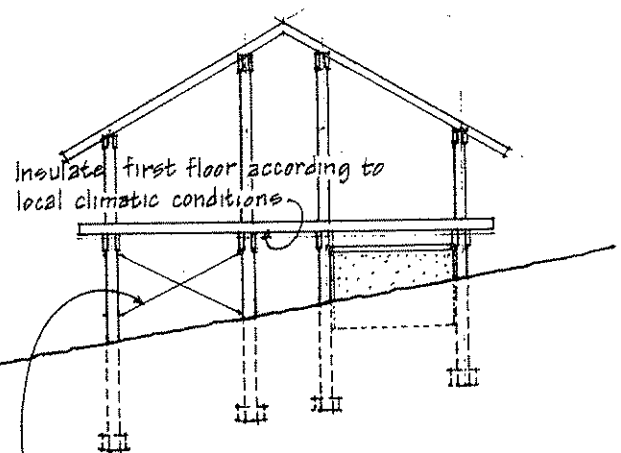
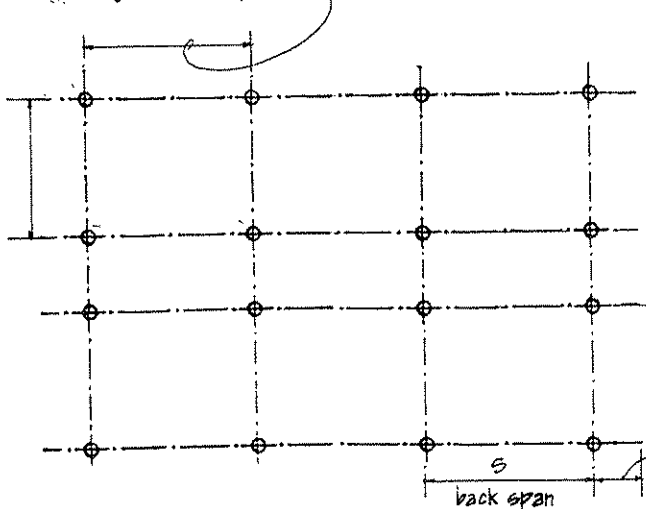


3.6 PIER FOUNDATIONS: WOOD



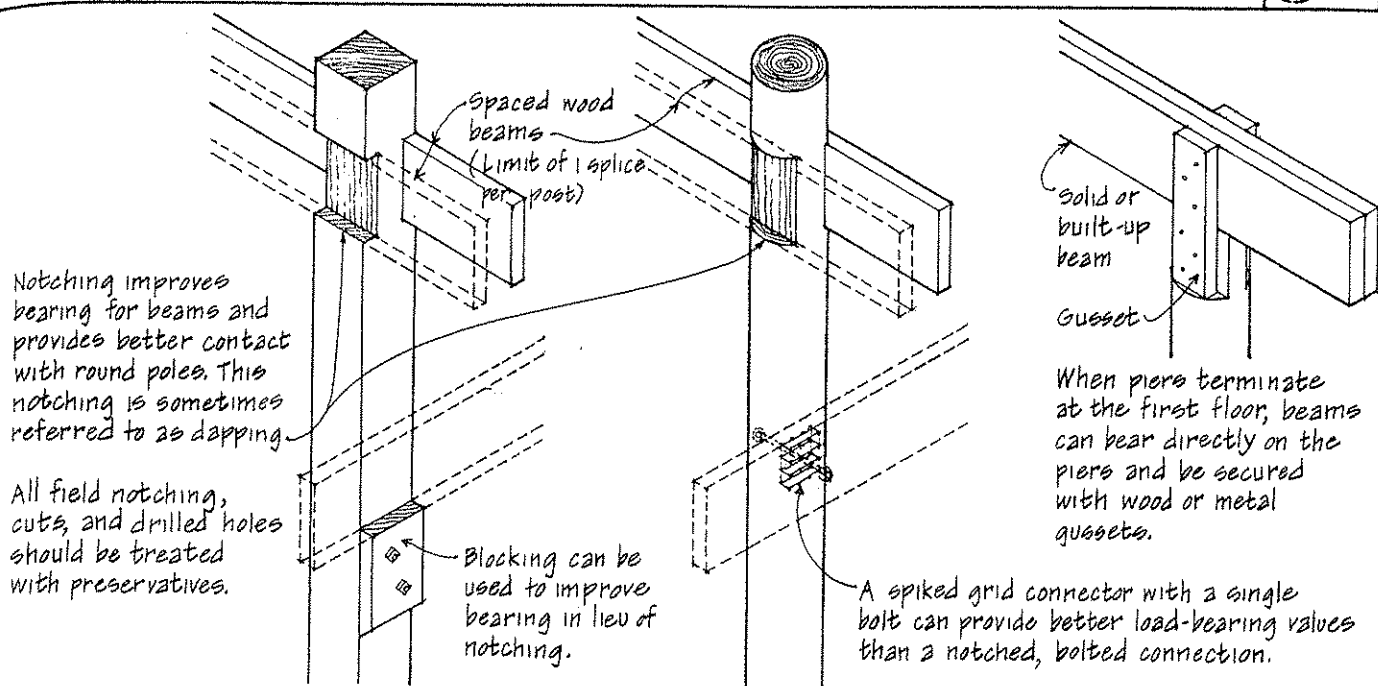
Wood pier foundations elevate timber structures above the ground plane, require minimal excavation, and preserve the natural features and existing drainage patterns of a site. They are particularly useful when building on steep slopes and in areas subject to periodic flooding or high winds.

Wood piers can be extended to support the roof and form a structure more resistant to lateral wind and seismic loads. These poles or posts are usually laid out along a grid defined by the beam and joist framing pattern. Their spacing determines both the beam and joist spans and the vertical loads they must support.



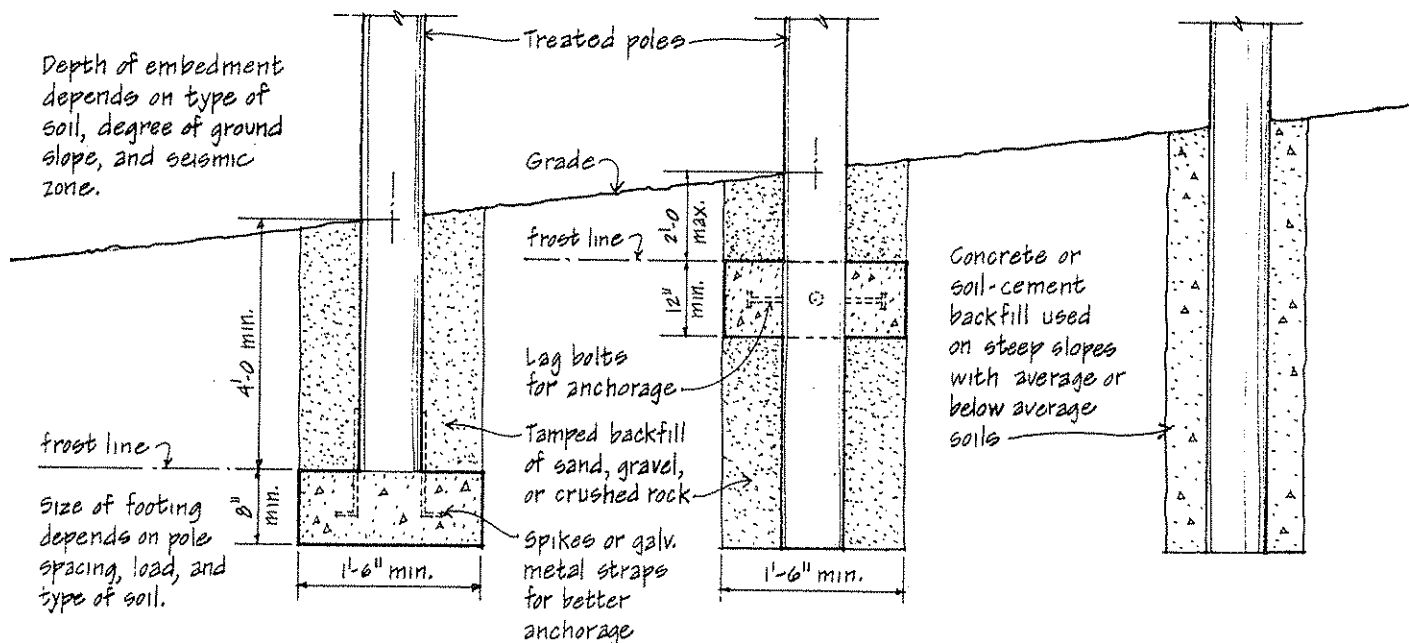
When adequate embedment is not possible, such as on rocky slopes, steel rod crossbracing with turnbuckles or shear walls of concrete or masonry can be used to provide lateral stability.

Limit cantilevers to 1/4 of the back span



Spaced beams are through-bolted to the sides of the supporting posts or poles, which can then continue up to serve as the load-bearing frame for the superstructure.

CONNECTIONS



FOOTINGS:

CONCRETE PAD

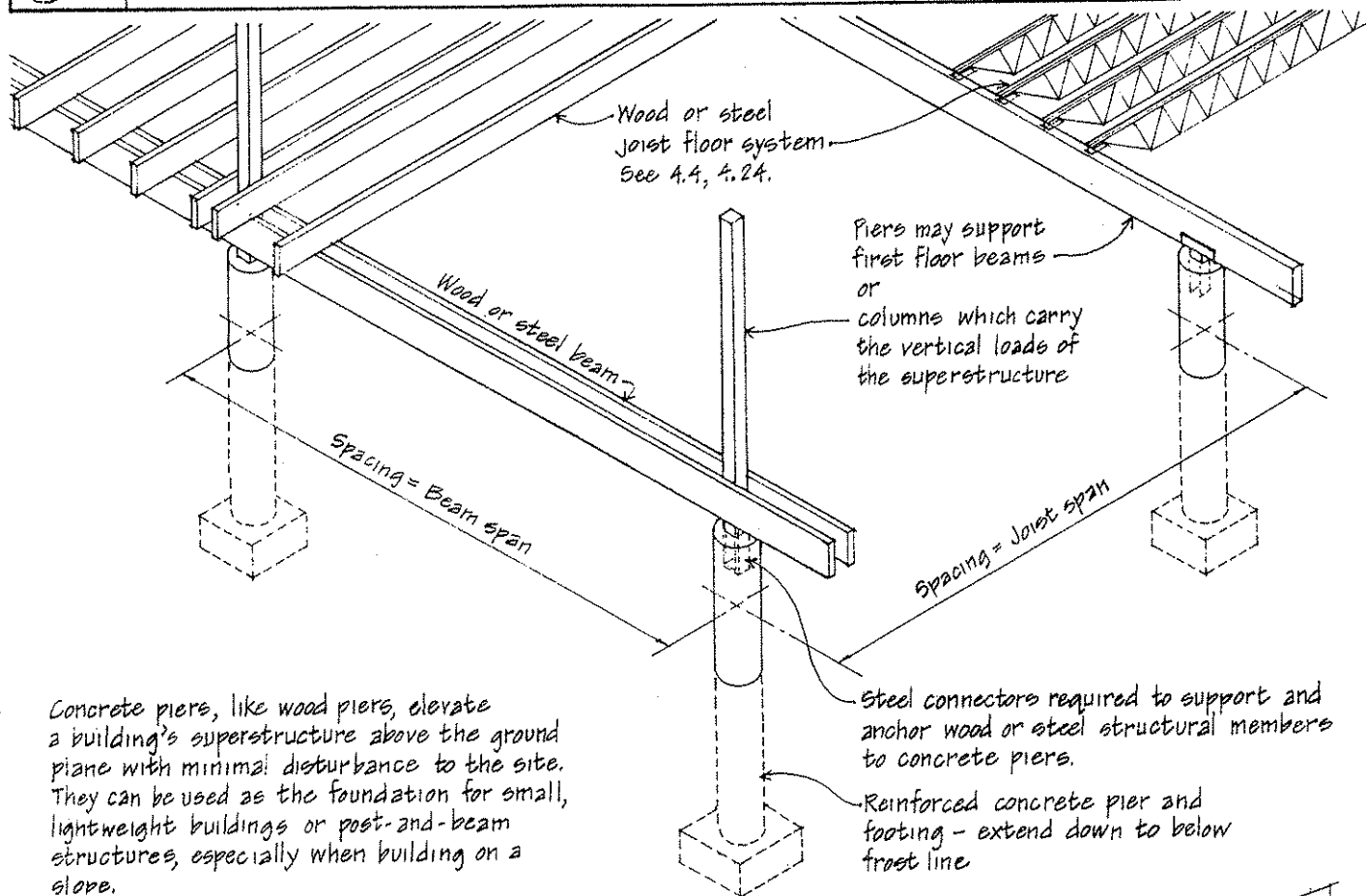
Poles are set in holes dug by hand or by a power auger. Concrete pads or collars increase the poles' contact with the soil and distribute their loads over a larger area.

CONCRETE COLLAR

CONC. BACKFILL

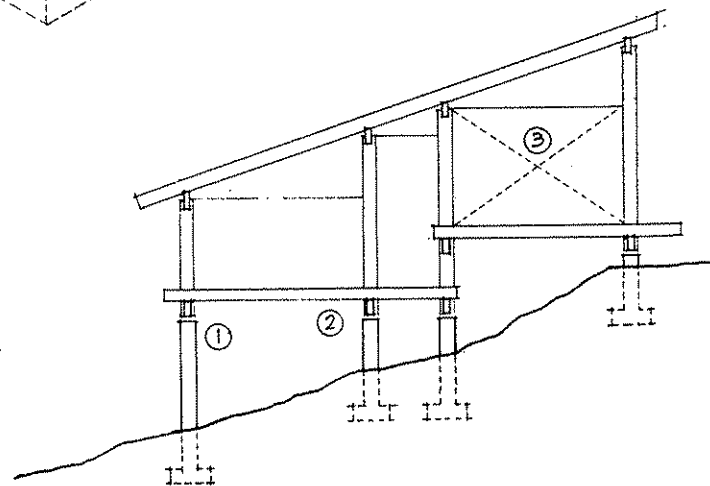
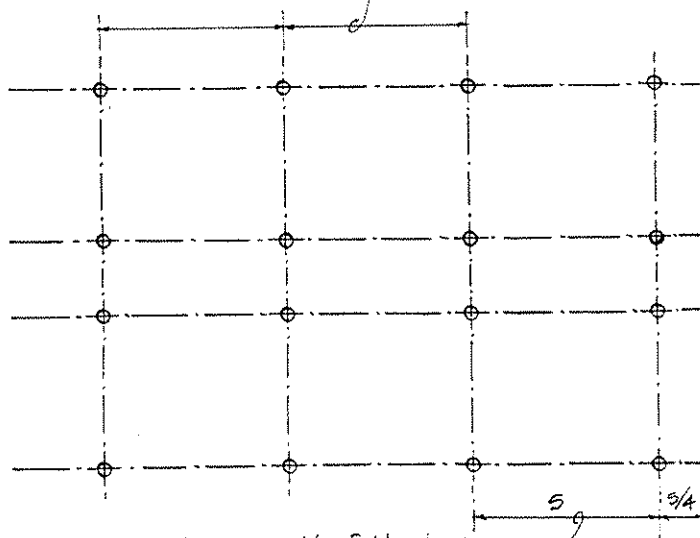
Poles can also be driven as end- or friction-bearing piles. When used in this manner, consult an engineer.

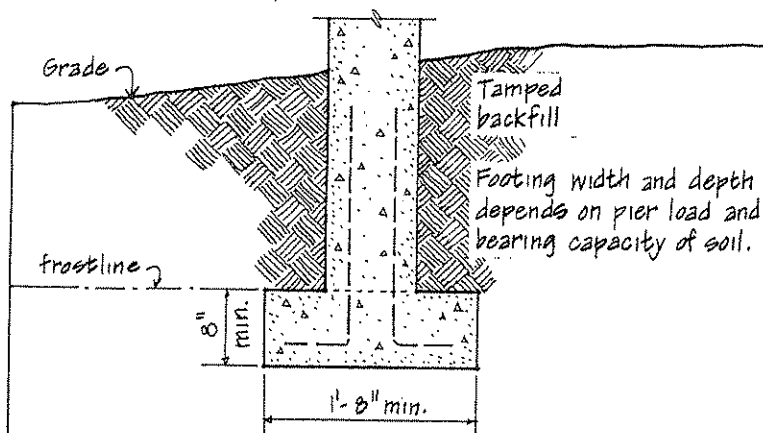
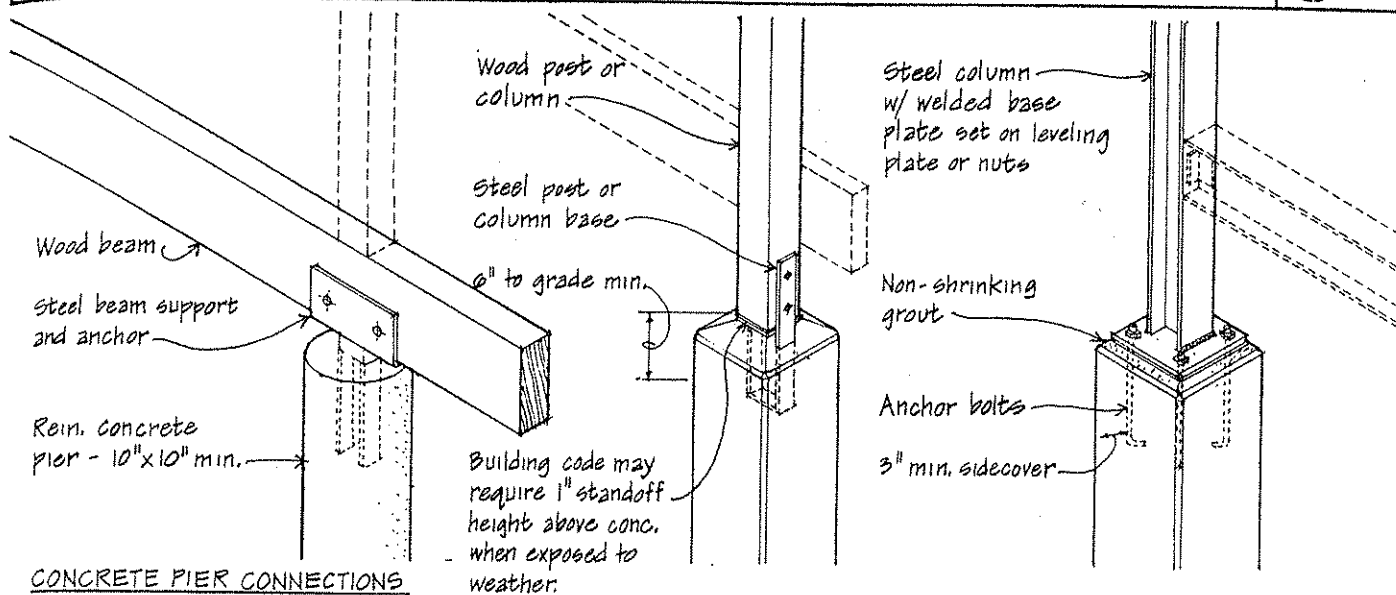
3.8 PIER FOUNDATIONS: CONCRETE



Concrete piers, like wood piers, elevate a building's superstructure above the ground plane with minimal disturbance to the site. They can be used as the foundation for small, lightweight buildings or post-and-beam structures, especially when building on a slope.

Concrete piers are usually laid out along a grid defined by the beam and joist framing pattern. Their spacing determines both the beam and joist spans and the loads they must support.





* See 5.44 for reinforced concrete columns.



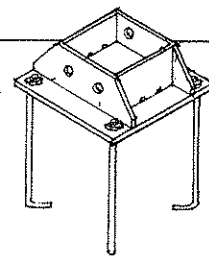
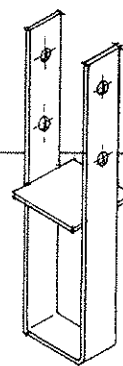
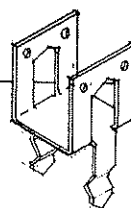
- Fiber forms
- Smooth or spiral pattern finish
- Disposable



- Clay tile or concrete pipe
- Left in place as finish



- Wood formwork
- Square or rectangular section
- Reusable

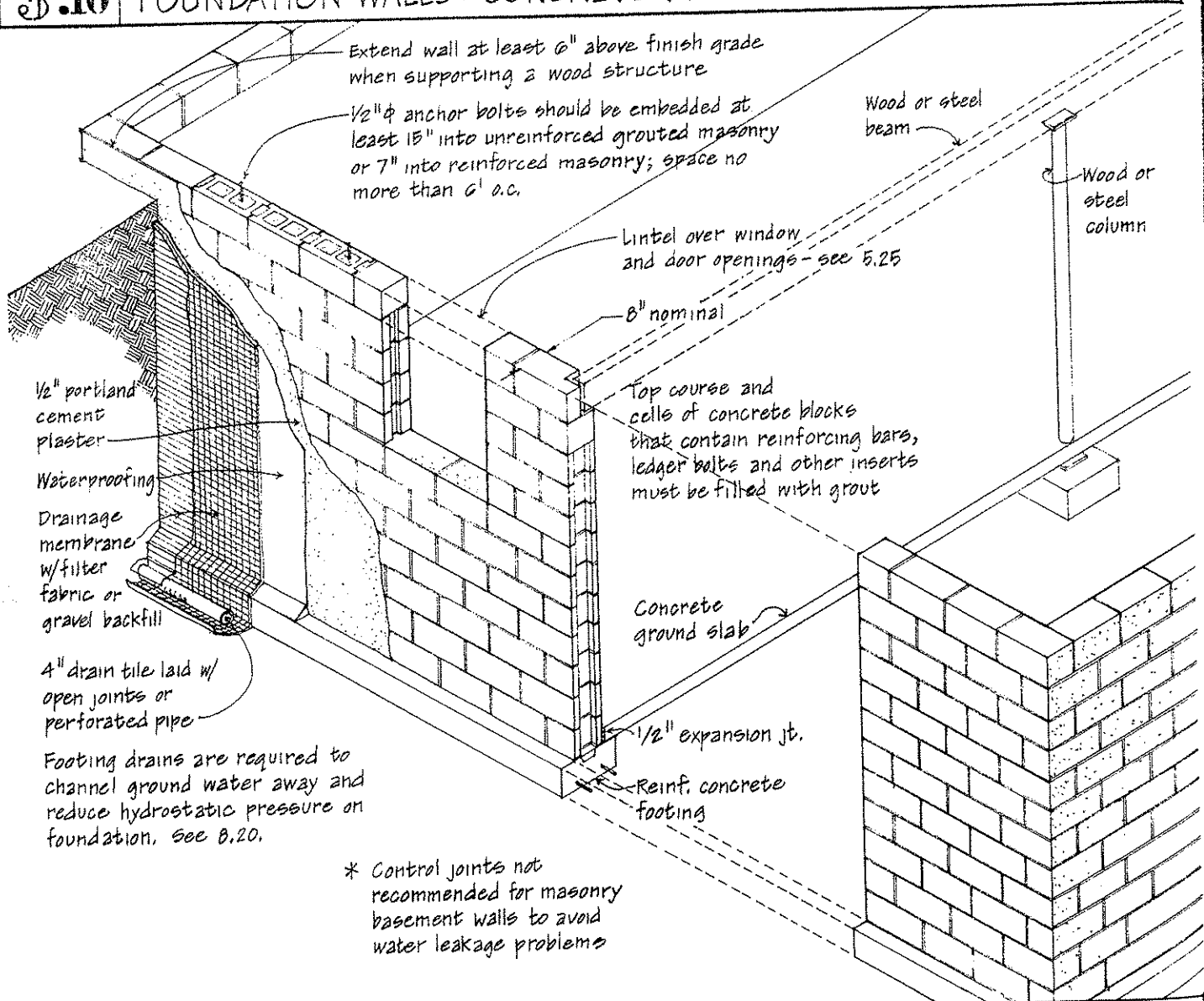


- A variety of proprietary post bases and beam anchors are available. Consult manufacturer for installation details and allowable loads.
- Post and beam connectors can also be shop fabricated to suit specific design conditions.
- Connectors should be galvanized or plated to resist corrosion when exposed to weather.

CONCRETE PIER FORMWORK

STEEL CONNECTORS

3.10 FOUNDATION WALLS: CONCRETE BLOCK

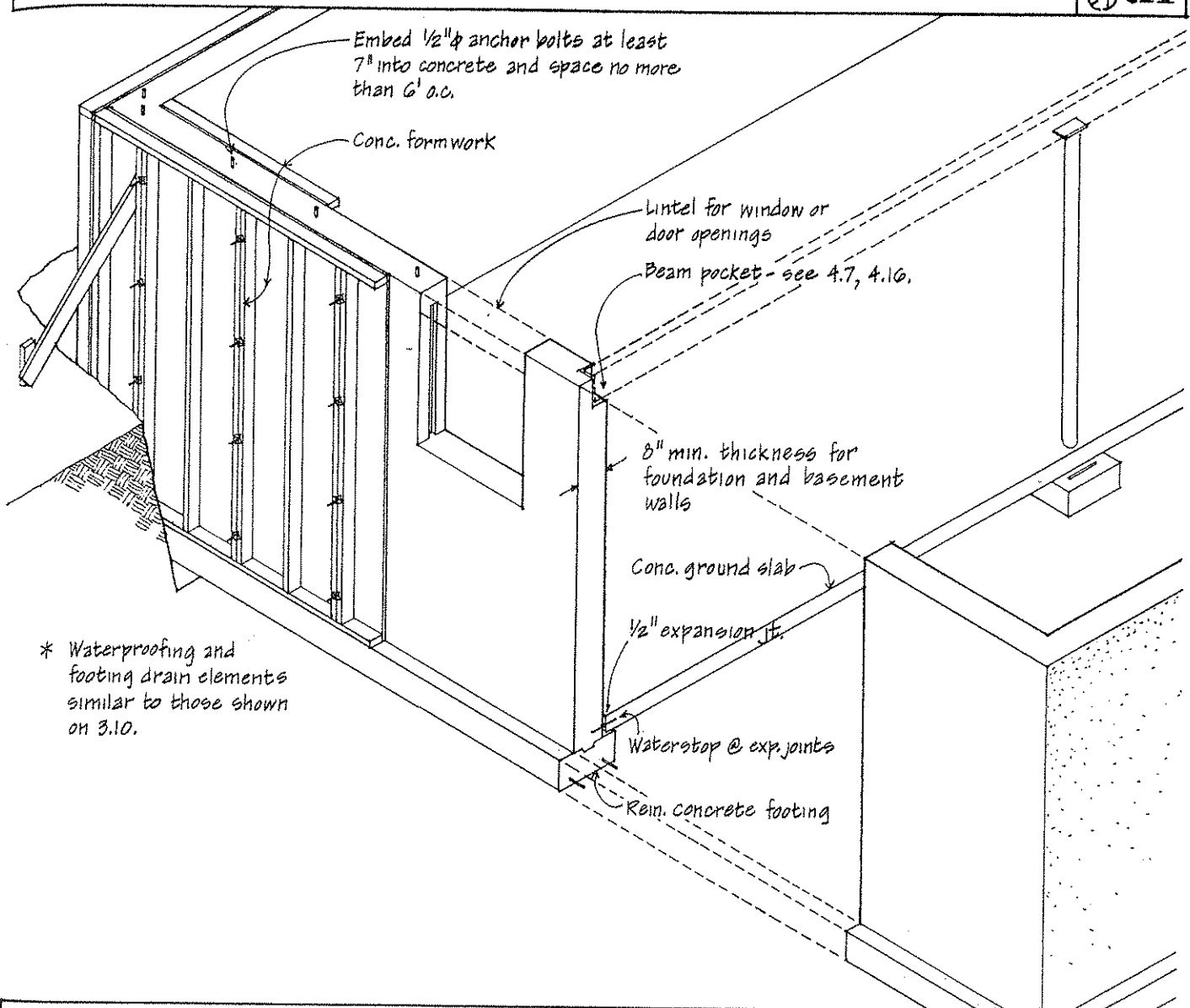


FOUNDATION WALL SYSTEMS • Thickness and reinforcement of foundation wall, and the size of its footing are determined by:

1. Building load and distribution pattern
 2. Type and bearing capacity of soil
 3. Lateral loading from soil and ground water
 4. Lateral bracing provided by basement ground slab and first floor system.
- Presence of ground water requires waterproofing of foundation walls and installation of footing drains.
 - Provide rough openings for windows and doors as well as pipe sleeves for water, sewer, gas, oil and electrical lines.
 - Type of floor and wall systems being supported will determine the top edge condition.

The form and support pattern of the foundation wall system should respond to the form of the superstructure as well as to the building site's soil and topographic conditions.

SITECAST CONCRETE



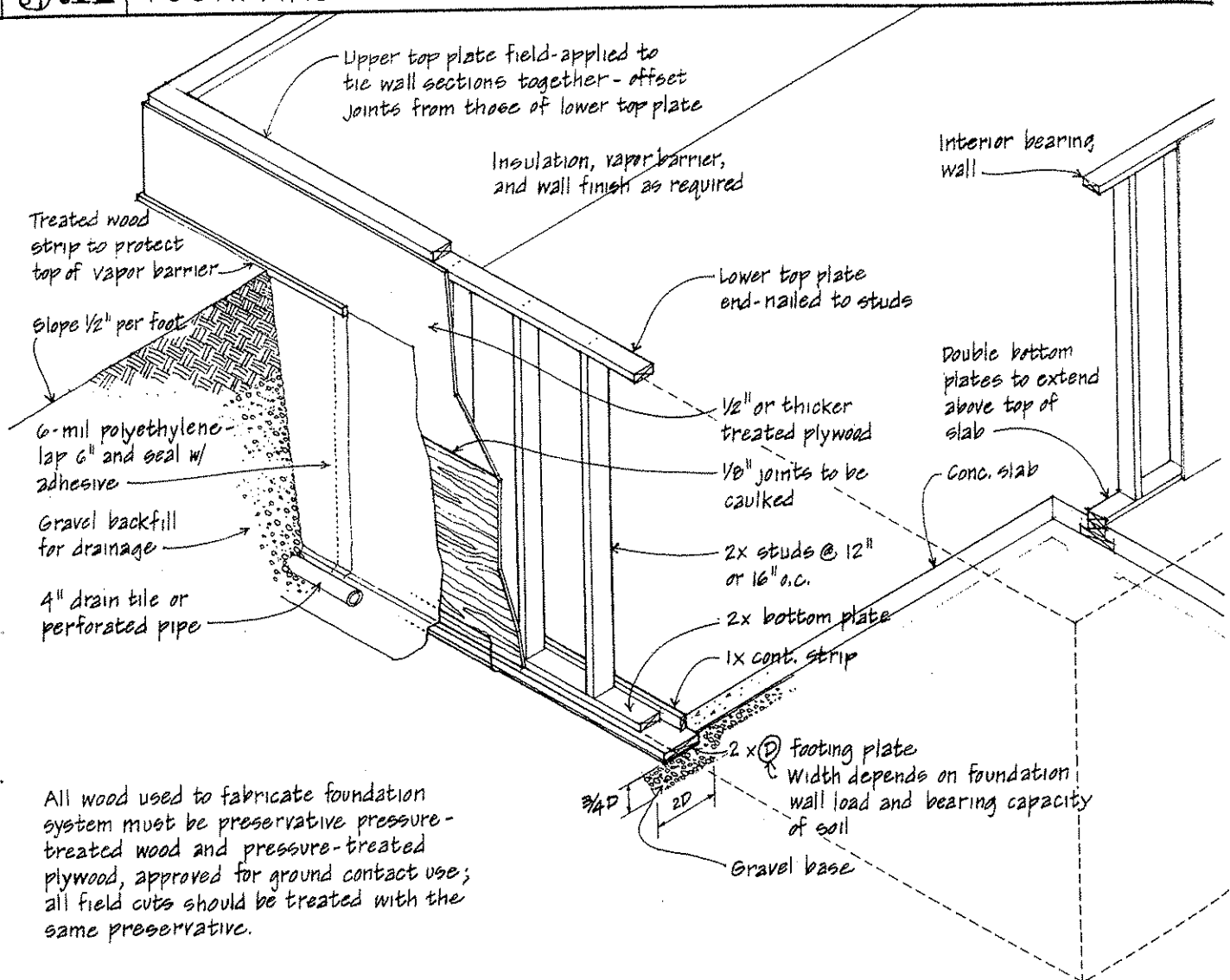
CONCRETE BLOCK FOUNDATION WALLS

- No formwork required; utilize easily handled small units; less erection time than for sitecast concrete walls
- Since concrete block is a modular material, all major dimensions (lengths, heights, offsets, wall openings) should be modular to minimize cutting of block.
- Concrete block walls are susceptible to differential settlement and cracking.
- See 5.22, 5.31.

SITECAST CONCRETE FOUNDATION WALLS

- Formwork and access to place concrete required
- Generally stronger but more expensive than concrete block foundations
- Modular dimensioning not necessary unless required by superstructure above

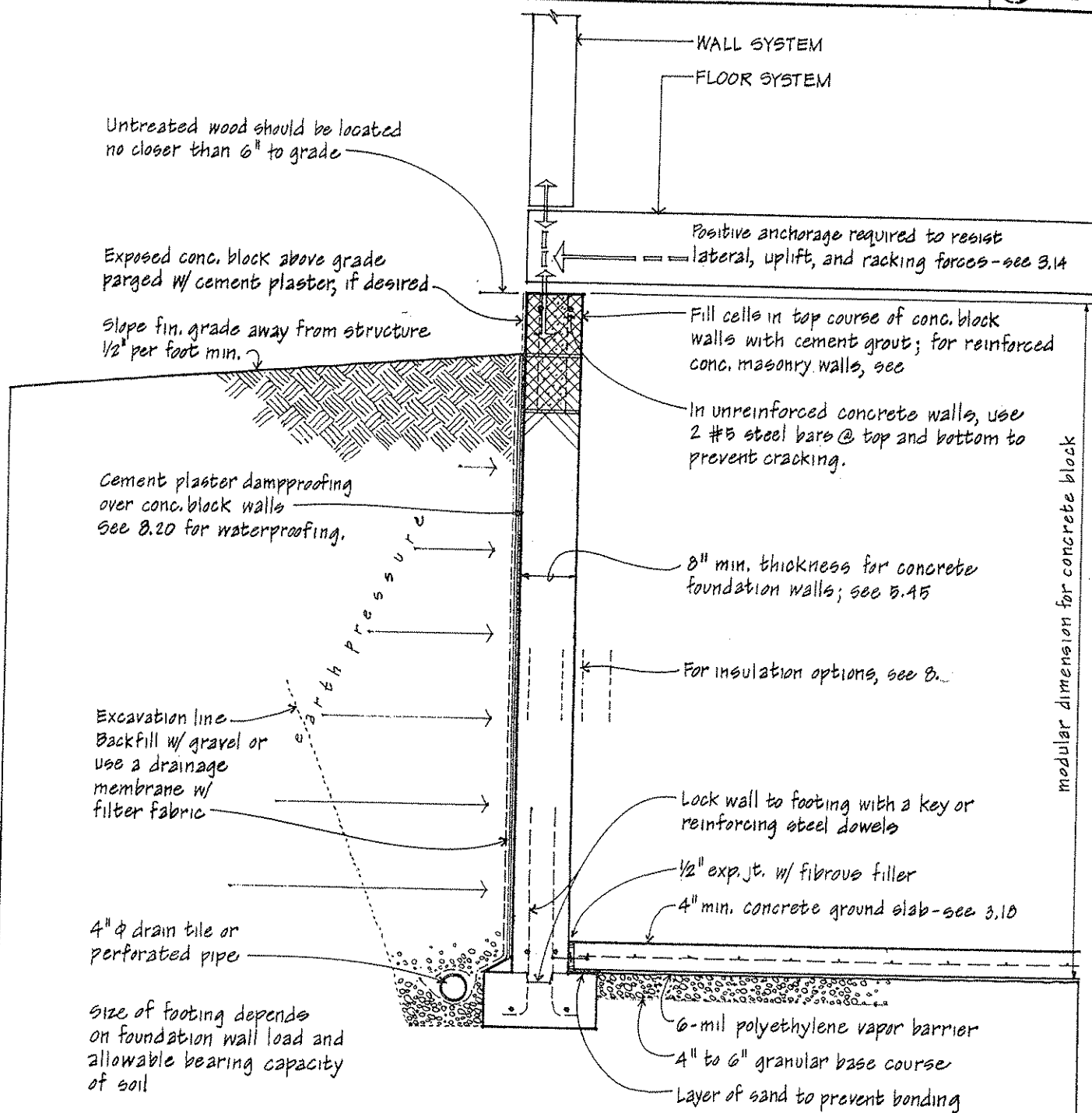
3.12 FOUNDATION WALLS: WOOD



WOOD FOUNDATION WALLS

- Wood foundation systems can be used for both basement and crawl space construction.
- Foundation wall sections may be factory fabricated or built on site; offers reduced erection time.
- Foundation walls supporting a first floor beam should be designed to carry the beam's concentrated load, and distribute it so that the allowable bearing capacity of the gravel base and soil is not exceeded.
- A sump may be required to ensure foundation drainage.

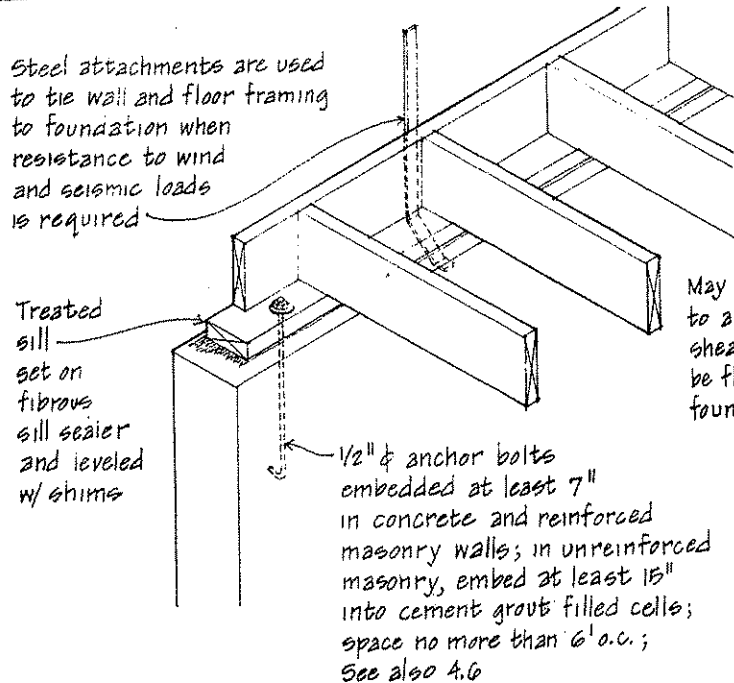
FOUNDATION WALL SECTION: SITECAST CONCRETE AND CONCRETE BLOCK



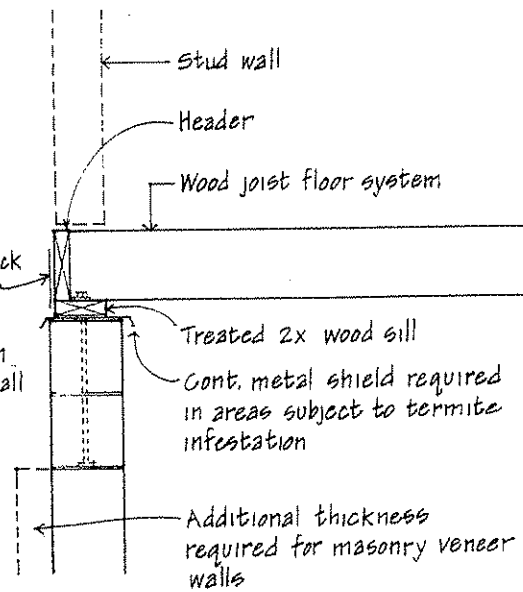
FOUNDATION WALL SECTION

Situations shown on this and pages 3.14-3.17 are applicable to both sitecast concrete and concrete block walls.

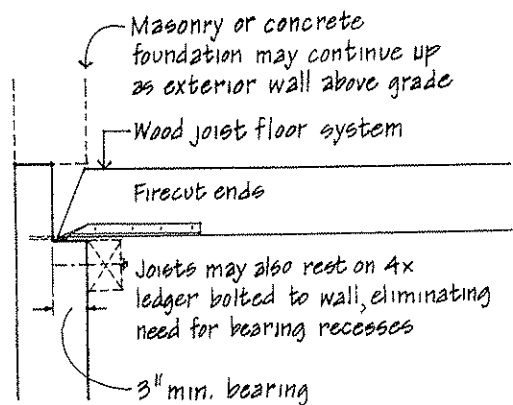
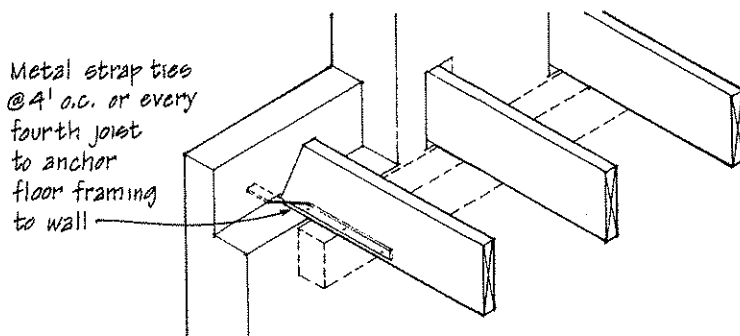
14 FOUNDATION WALL • FLOOR SYSTEM CONNECTIONS



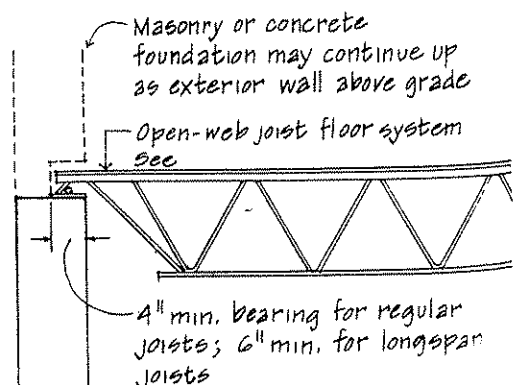
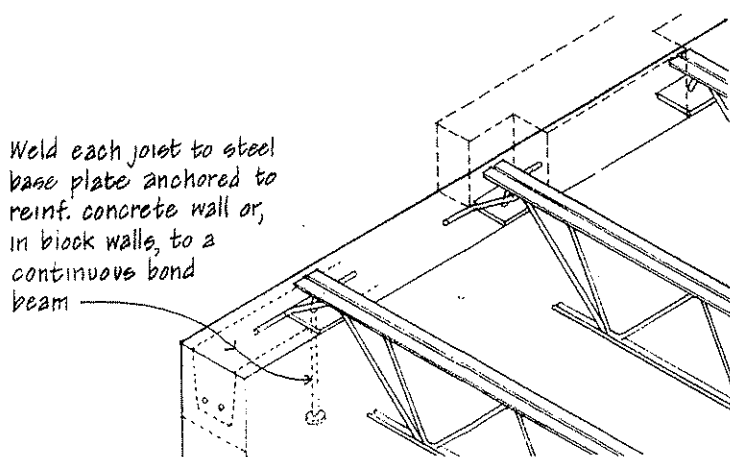
May be set back to allow wall sheathing to be flush with foundation wall



WOOD JOISTS SET ON FOUNDATION WALL

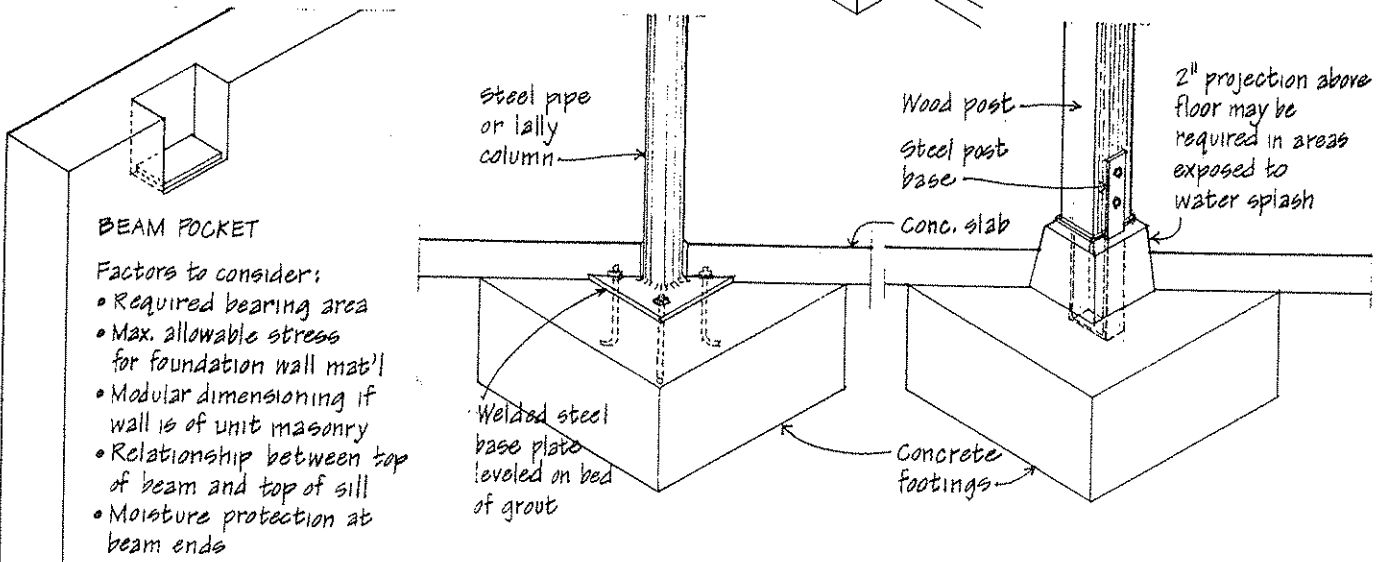
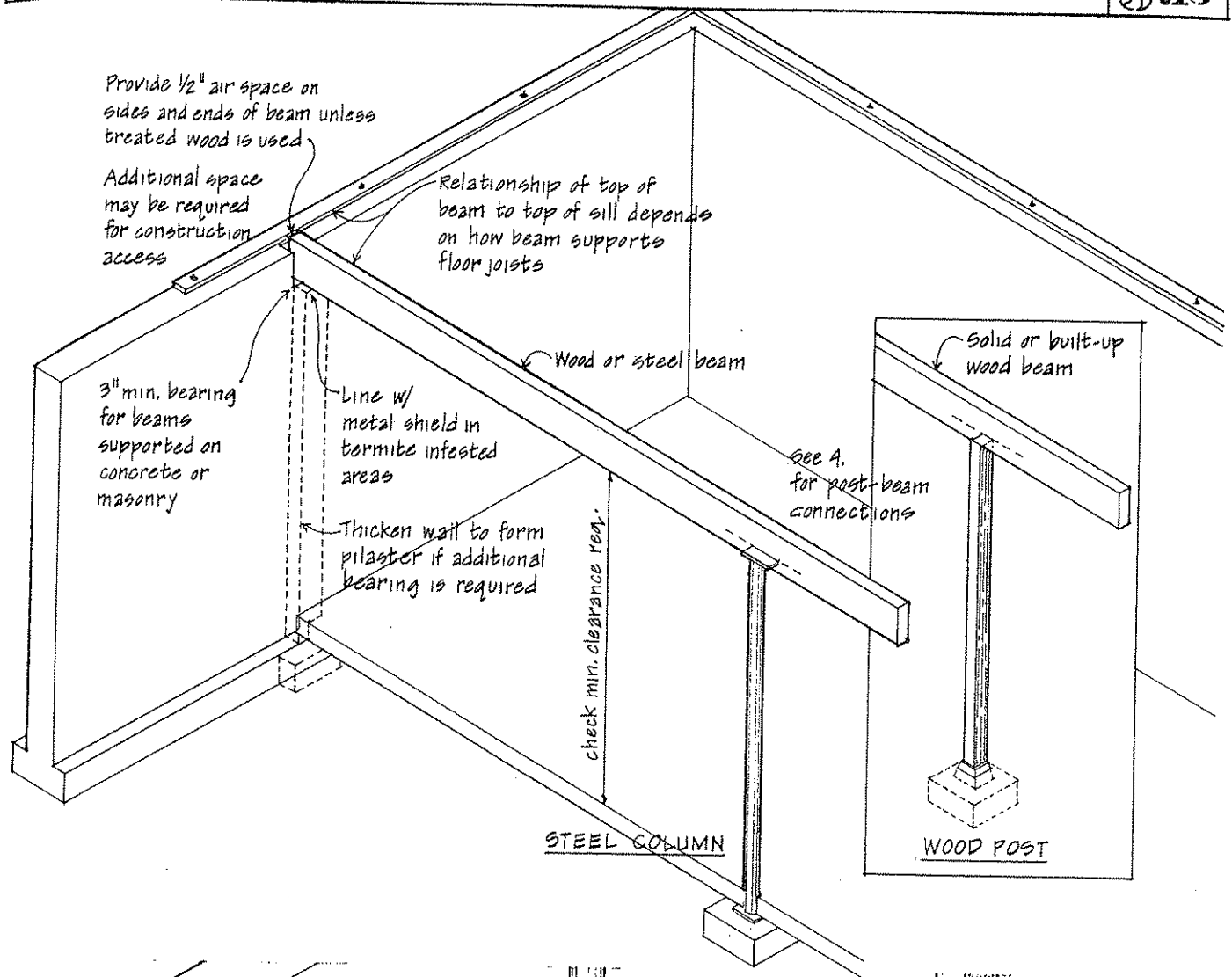


WOOD JOISTS SET INTO FOUNDATION WALL



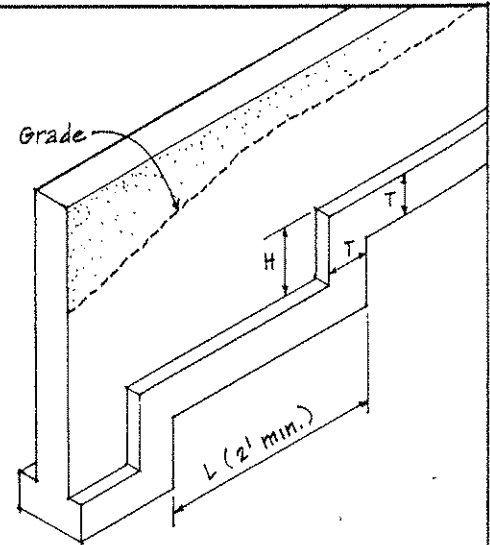
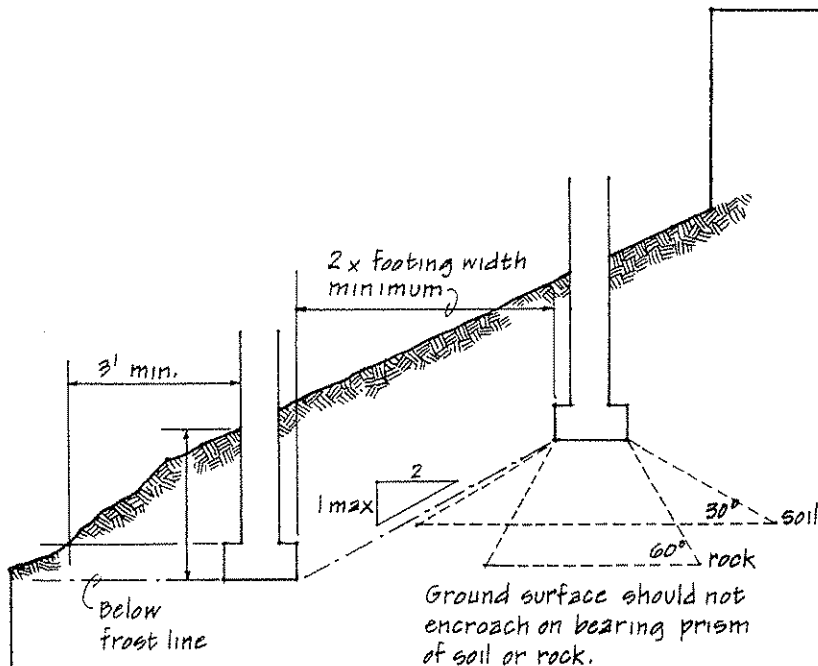
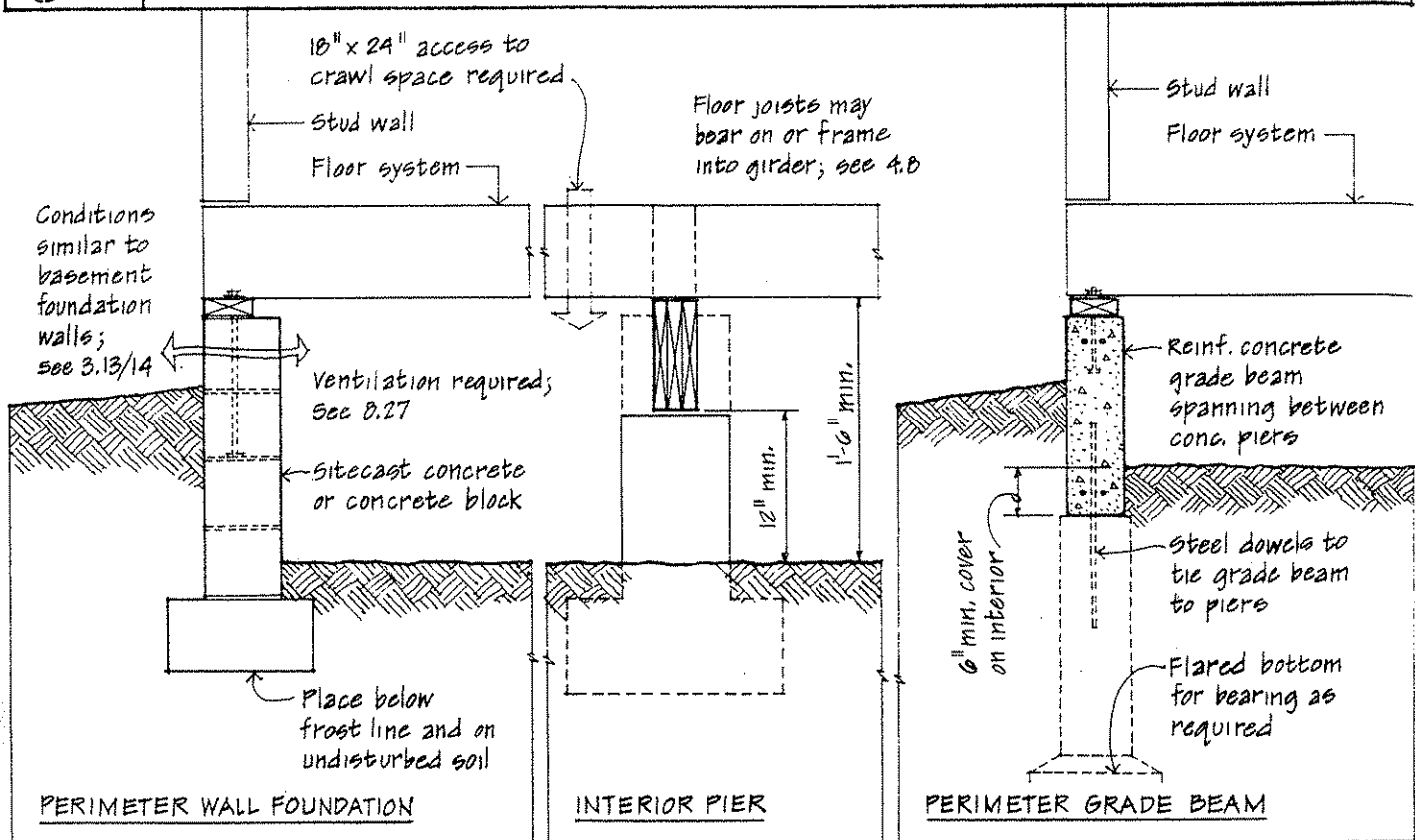
OPEN-WEB STEEL JOISTS SET ON OR INTO FOUNDATION WALL

INTERIOR COLUMN • BEAM SUPPORTS



COLUMN BASE FOOTINGS

5.16 FOUNDATION WALLS: CRAWL SPACE CONDITION

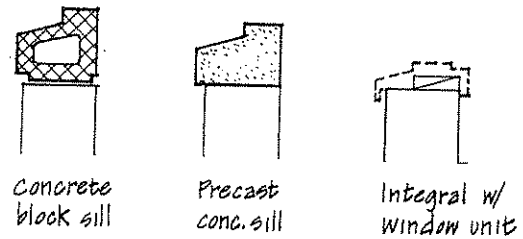
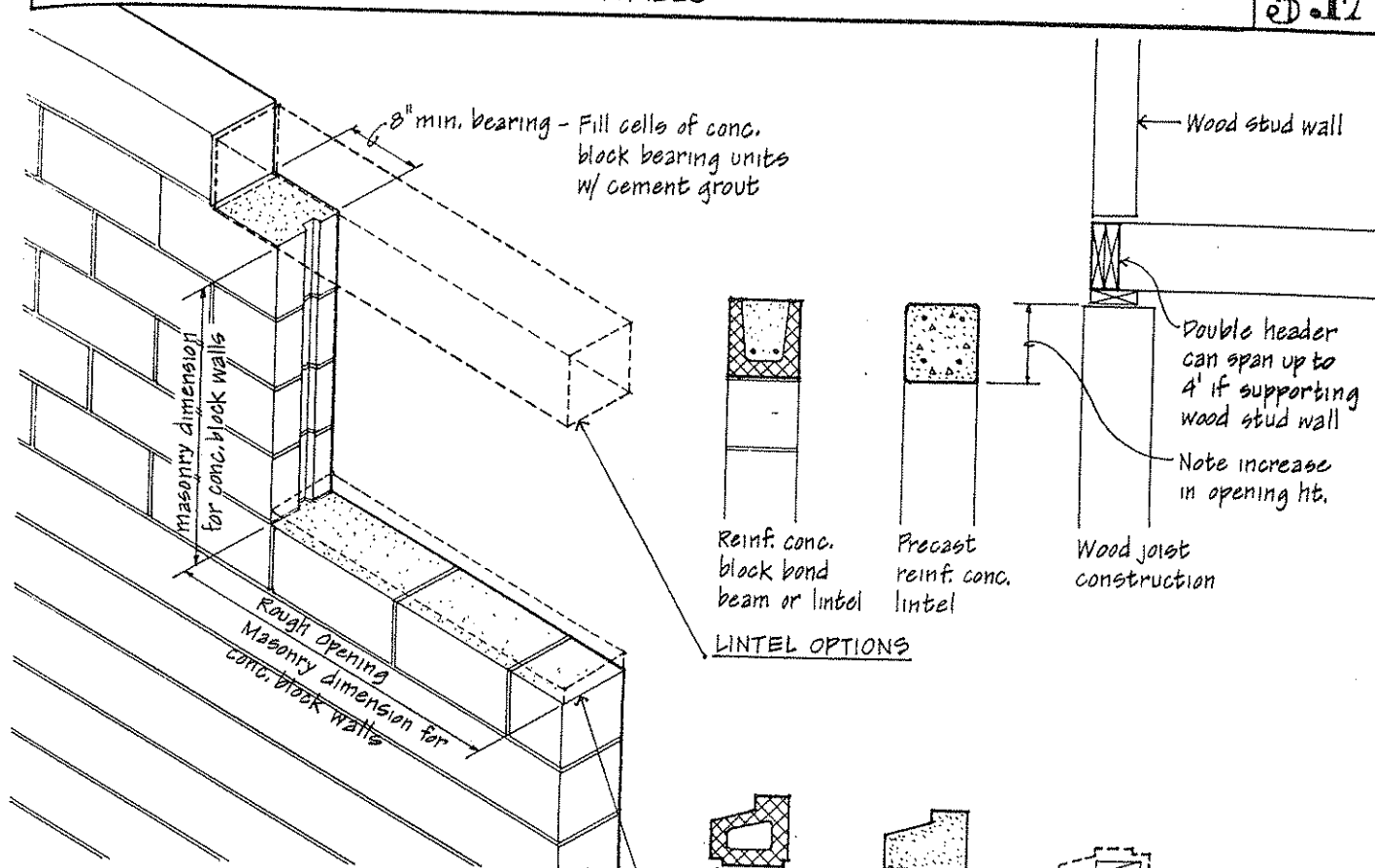


- Maintain thickness of footing (T) in vertical step
- Vertical step (H) should be less than half of L and limited to 2' where possible
- Use modular dimensions for concrete block walls

STEPPED FOOTINGS

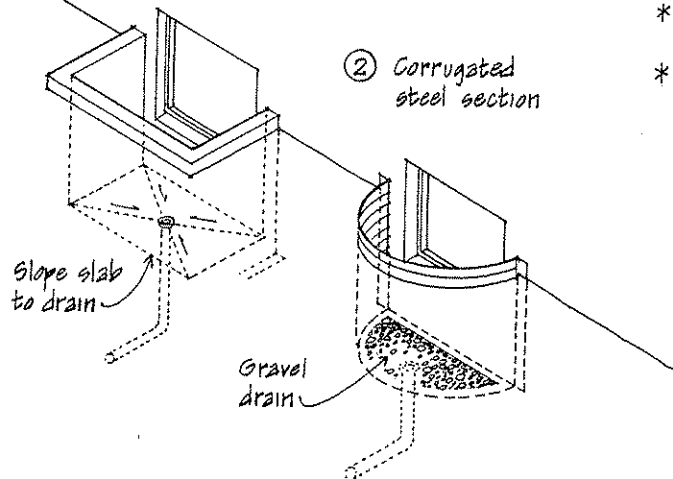
OPENINGS IN FOUNDATION WALLS

5.17



① Cast-in-place concrete or concrete block

② Corrugated steel section

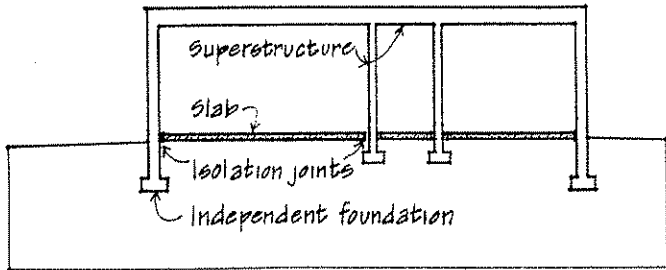


* Verify rough opening requirements with door or window manufacturer.

* See 5.24 for more information on concrete block wall openings.

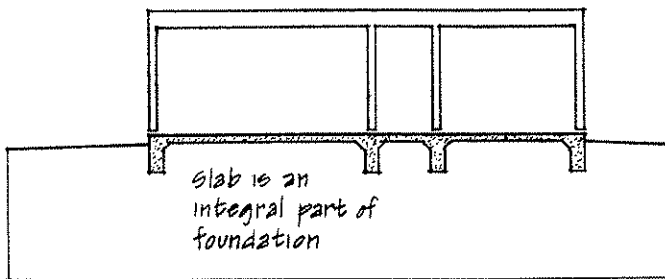
BASEMENT WINDOW AREAWAYS

3.18 CONCRETE GROUND SLABS



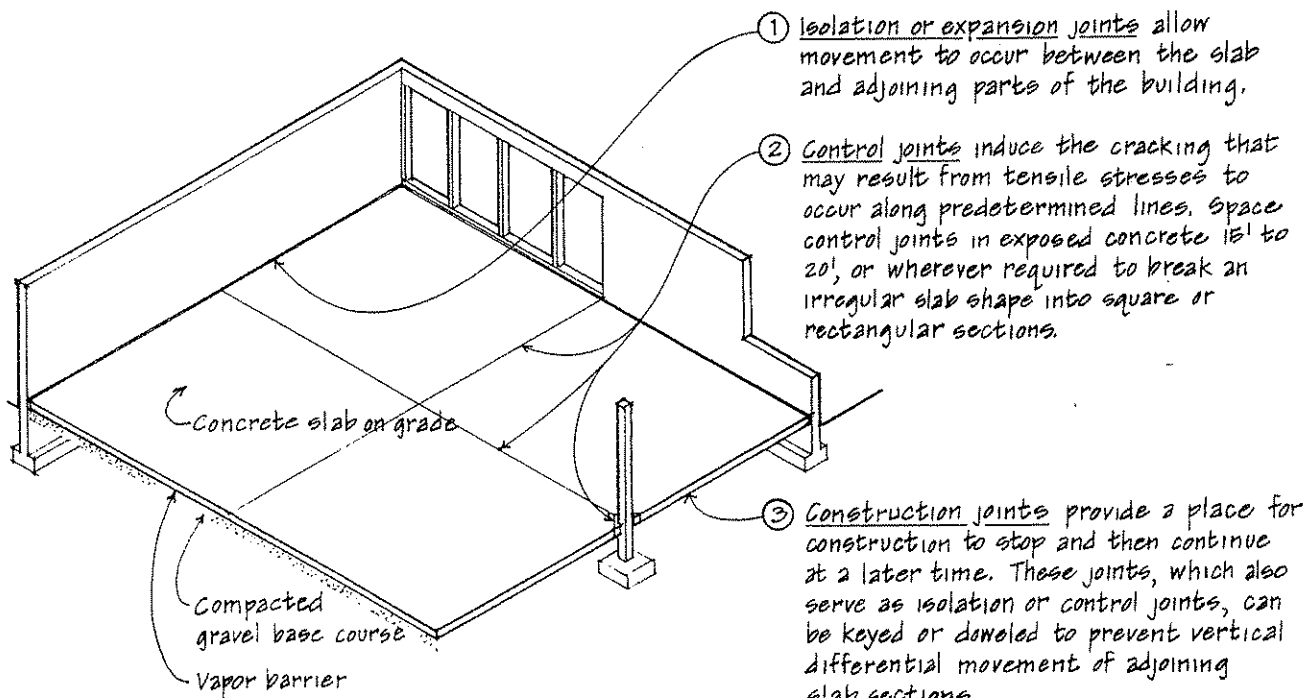
- 4" min. slab thickness
- Should rest on stable, compacted soil with no organic matter
- Does not carry any superstructure loads
- Reinforced with steel mesh fabric which controls thermal stresses, shrinkage cracking, and slight differential movement in the soil bed

GROUND-SUPPORTED SLAB



- Used over problem soils
- Structural reinforcement enables slab to act as a monolithic unit with foundation
- Superstructure loads are distributed over entire slab area
- Requires engineering analysis and design

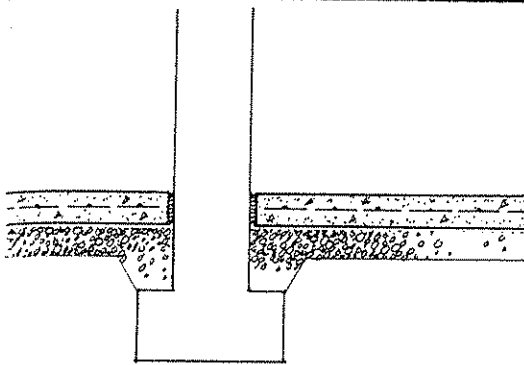
STRUCTURALLY-REINFORCED SLAB



TYPES OF JOINTS

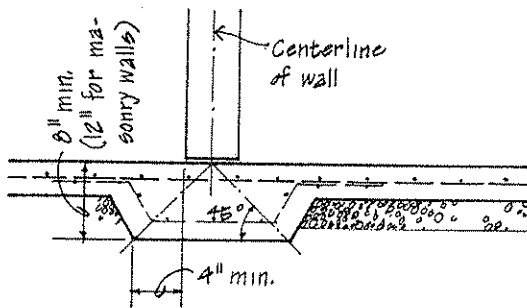
CONCRETE GROUND SLABS: FOUNDATION AND WALL SYSTEM CONNECTIONS

19



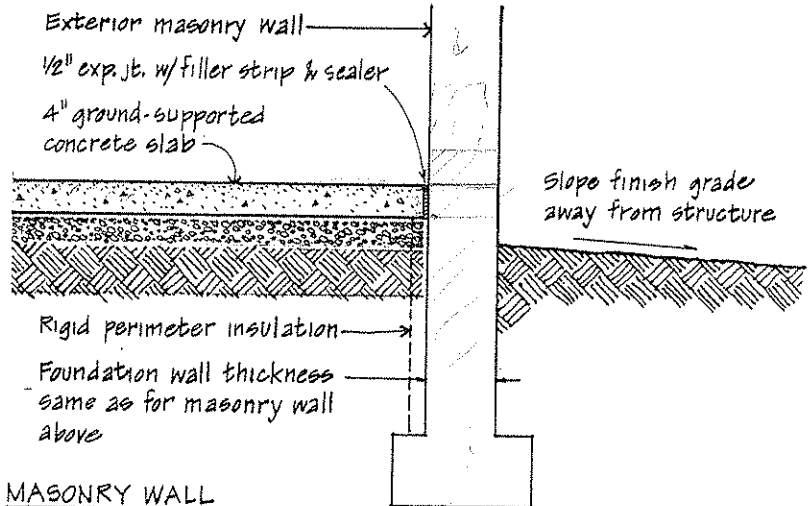
An independent footing is used when the bearing partition carries a heavy or concentrated load.

INDEPENDENT FOOTING

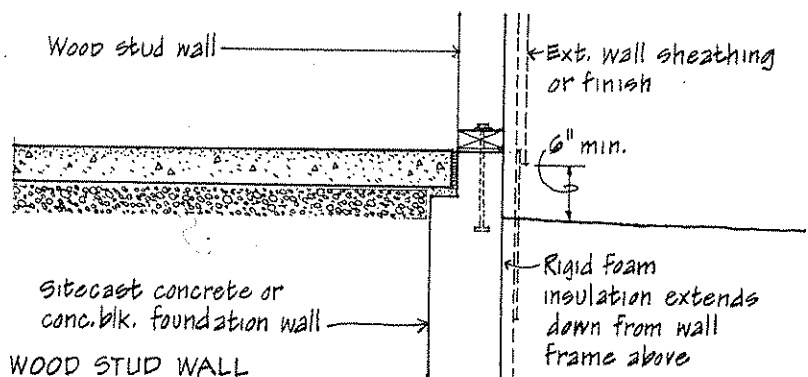


INTEGRAL FOOTING

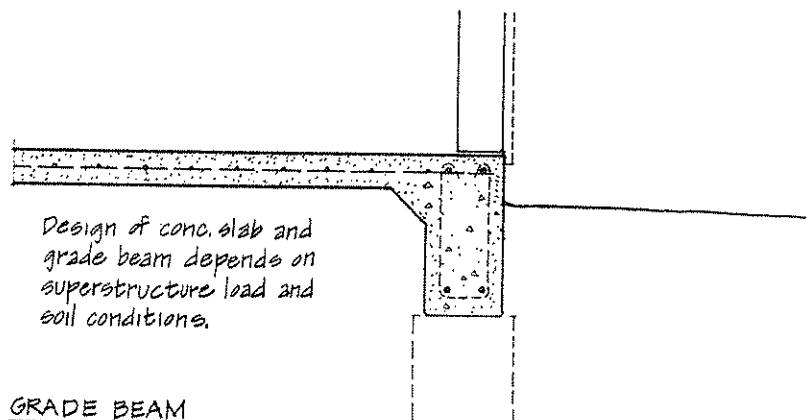
The slab under a bearing partition can be thickened to serve as a footing. Width and depth of footing depends on wall thickness and load, and the soil condition.



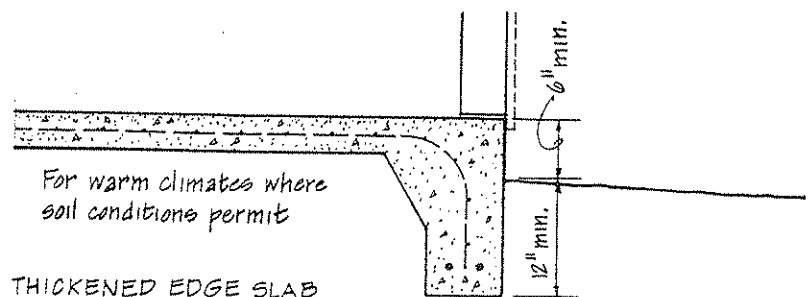
MASONRY WALL



WOOD STUD WALL



GRADE BEAM

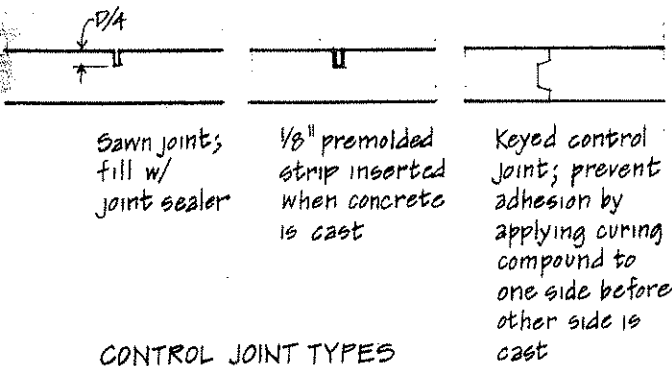


THICKENED EDGE SLAB

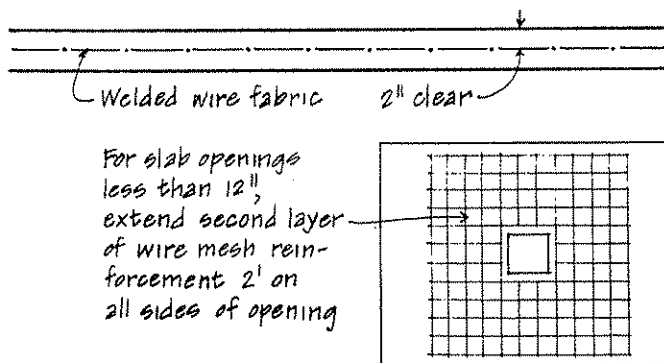
5.20 CONCRETE GROUND SLABS: FLOOR CONDITIONS

- ① Vapor barrier prevents ground moisture from penetrating slab; may be either 6-mil polyethylene sheet or glass fiber reinforced waterproofing paper.
4" min. conc. slab
- ② Gravel base course limited capillarity prevents ground water to rise through slab bed; 4" to 6" deep.
- ③ Compacted fill increases soil stability, loadbearing capacity, and resistance to water penetration.

THE SLAB BED

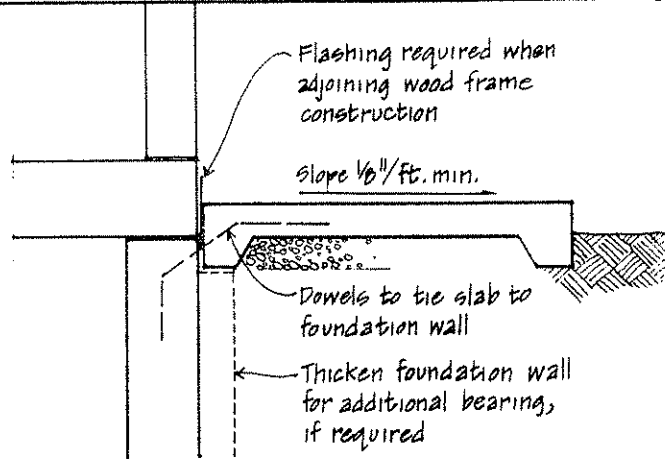


CONTROL JOINT TYPES

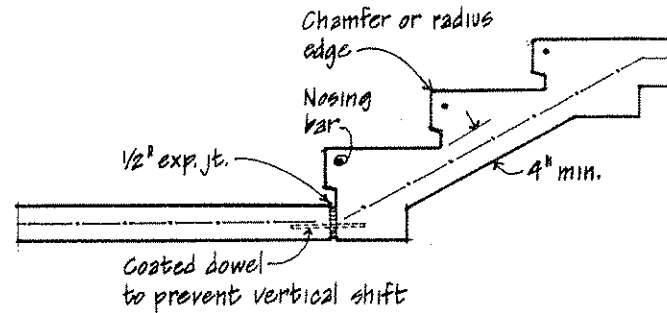


WIRE MESH REINFORCEMENT

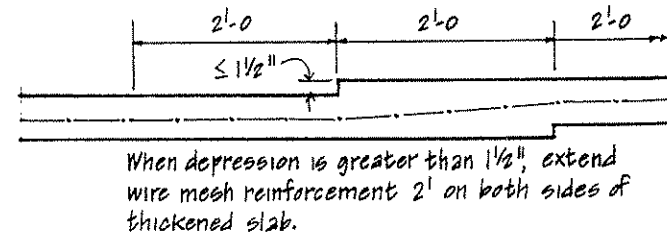
Max. slab dimension (feet)	Wire spac'g (inches)	Wire gage (number)
Up to 45	6 x 6	10/10
45 to 60	6 x 6	8/8
60 to 75	6 x 6	6/6



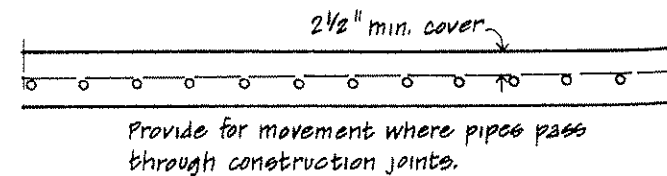
EXTERIOR SLAB



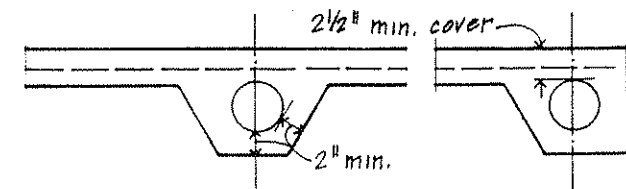
SLAB STEPS



SLAB DEPRESSIONS



EMBEDDED HEATING PIPES



HEATING DUCTS

FLOOR SYSTEMS

Floor systems are a building's primary horizontal planes which must support both live loads—people, furnishings, and movable equipment—and dead loads—the weight of the floor construction itself. Floor systems must transfer their loads horizontally across space to either beams and columns or to bearing walls. Rigid wall planes can also serve as horizontal diaphragms which act as thin, wide beams spanning between shear wall planes.

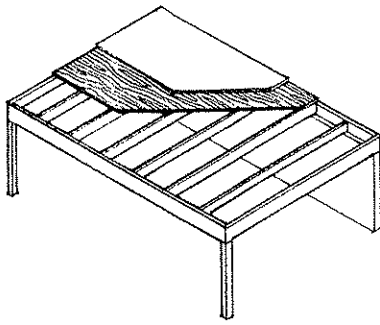
A floor system may be composed of a series of linear beams and joists overlaid with a plane of sheathing or decking, or it may consist of a nearly homogeneous slab of reinforced concrete. The depth of a floor system is directly related to the size and proportion of the structural bays it must span and the strength of the materials used. The size and placement of any cantilevers and openings within the floor plane should also be considered in the layout of a floor system's structural supports. A floor system's edge conditions and connections to supporting foundation and wall systems affect both a building's structural integrity and its physical appearance.

Since it must safely support moving loads, a floor system should be relatively stiff while maintaining its elasticity. Due to the detrimental effects that excessive deflection and vibration would have on finish flooring and ceiling materials, as well as concern for human comfort, deflection rather than bending becomes the critical controlling factor.

The depth of the floor construction and the cavities within it should be considered if it is necessary to accommodate runs of mechanical or electrical lines within the floor system. For floor systems between living spaces stacked one above another, an additional factor to consider is the blockage of both airborne and structure-borne sound.

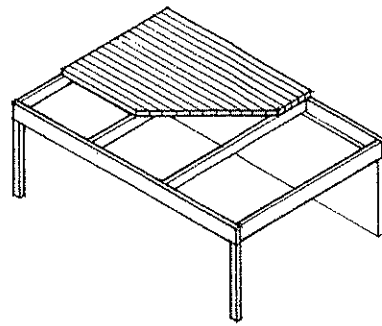
Except for exterior decks, a building's floor systems are normally not exposed to weather. Since they all must support traffic, however, durability, resistance to wear, and maintenance requirements are factors to consider in the selection of a floor finish and the system required to support it.

4.2 COMPARATIVE FLOOR SYSTEMS



Wood joist system

- Relatively small joist members closely spaced
- Joists supported by either beams or walls



Wood plank and beam

- Larger beams spaced further apart and spanned with structural planking or decking
- Beams supported by girders, posts, or walls

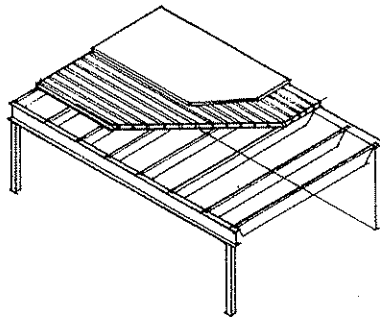
Wood joist floor system

- Relatively short spans for subflooring, underlayment, and applied ceiling
- Flexible in form and shape

Wood plank and beam system

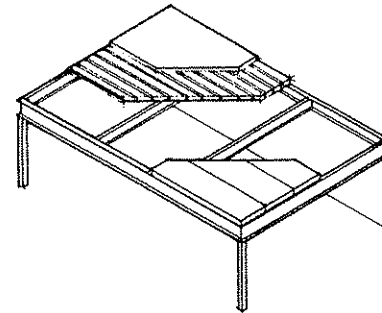
- If underside of construction is left exposed, it is more difficult to run concealed mechanical and electrical lines, and the system is less resistant to sound transmission
- Concentrated loads and floor openings may require additional framing

WOOD



Steel joist system

- Light-gauge or open-web joists closely spaced
- Joists supported by beams or walls



Steel beam and decking

- Heavier beams spaced further apart and spanned with steel decking or precast concrete planks
- Beams supported by girders, columns, or walls

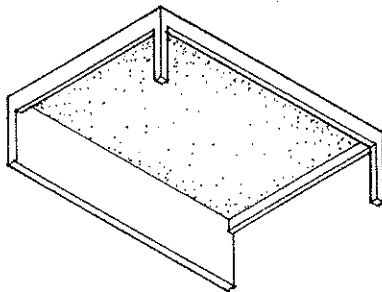
Steel joist floor system

- Relatively short spans for decking
- Underside of structure may be left exposed, or have a ceiling applied
- Limited cantilever potential

Steel beam and decking system

- Typically an integral part of a steel skeleton frame system
- Concentrated loads and floor openings may require additional framing

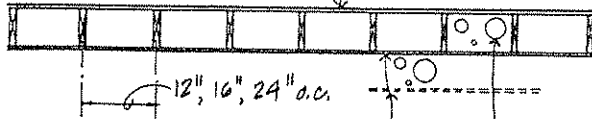
STEEL



CONCRETE

- Precast or cast-in-place
- Concrete floor systems are classified according to the type of span and the resulting form:
 - One-way and two-way slabs
 - One-way joist slab
 - Two-way waffle slab
 - Two-way flat slab
 - Two-way flat plate
- Factors in system choice include the type and magnitude of load conditions, the desired floor depth, and the desired size and proportion of the structural bays

Subfloor and underlayment
for finish flooring



Ceiling applied directly
to underside of joists or
suspended from joists

Mechanical and electrical lines
normally run parallel to joists; may
run perpendicular to and penetrate
joists under certain conditions

WOOD JOIST SYSTEM

Finish wood flooring over decking;
resilient tile and similar flooring require
underlayment; decking may be left
exposed in rough construction

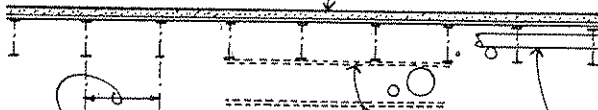


Applied ceiling optional;
Underside may be left exposed

Mechanical and electrical lines may be
run within spaced beams for concealment

WOOD PLANK AND BEAM SYSTEM

Concrete fill or slab over
steel floor decking



24" or greater,
depending on floor
load and spanning
capability of deck

Underside of structure may
be left exposed, or a ceiling may
be hung from joists

Mechanical and electrical lines may run
parallel or perpendicular to open-web joists

STEEL JOIST SYSTEM

Precast conc. planks, or conc. fill or slab
over steel floor decking



Beam size and spacing
related to floor load,
beam span, and spanning
capability of deck

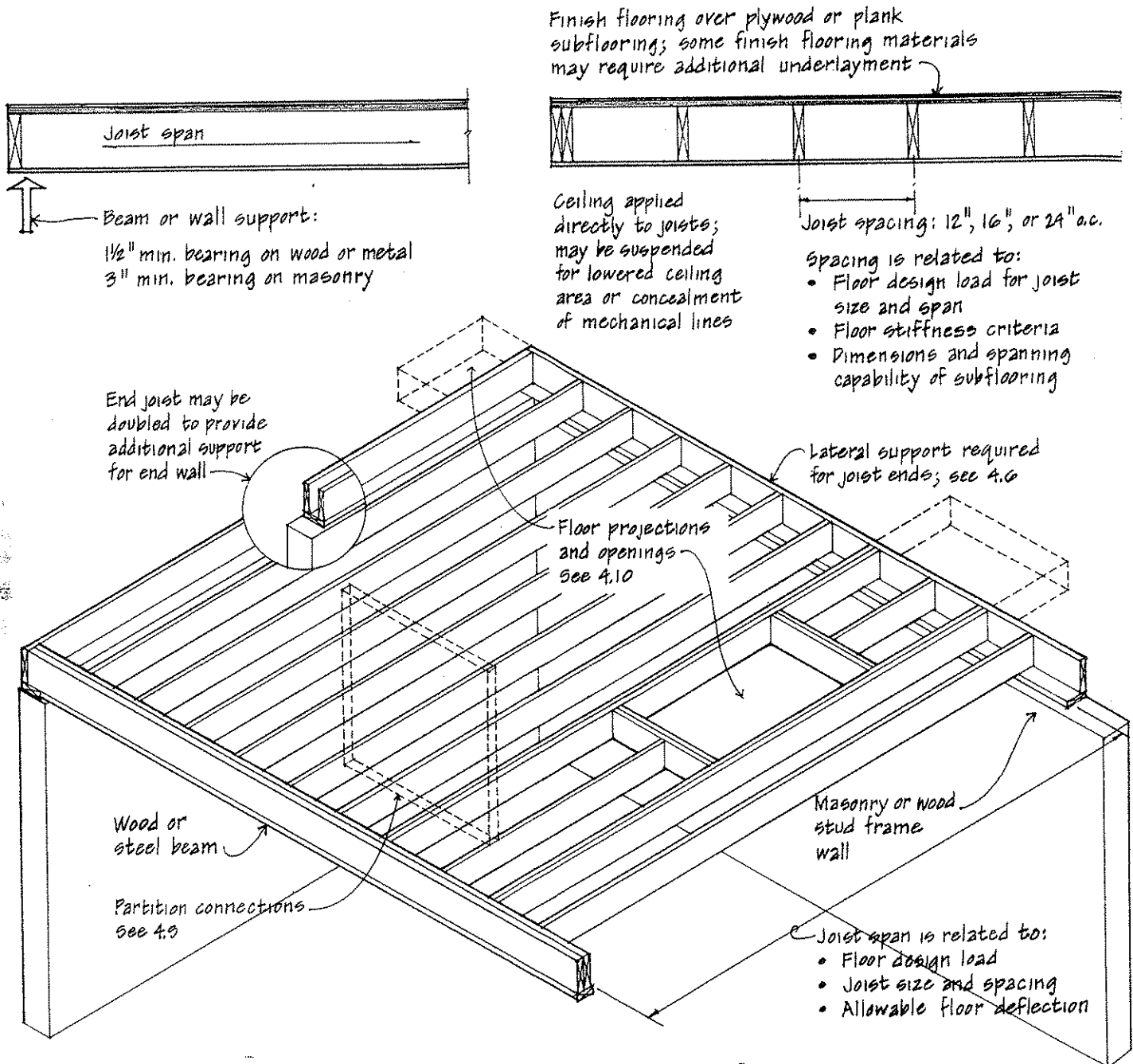
Underside of structure may be left
exposed, or a ceiling may be suspended
from deck

Mechanical and electrical lines run parallel to
beams, or perpendicular to and beneath beams;
may penetrate beams under certain conditions

STEEL BEAM AND DECKING

* See 4.32-4.33 for overview of concrete floor systems.

4.4 WOOD JOIST FLOOR SYSTEM



WOOD JOIST FLOOR SYSTEM

- Most typical wood floor system
- Flexible in form and shape because of the workability of the material, the relatively small pieces, and the various means of fastening available
- Fire-resistance rating depends on finish floor and ceiling materials

WOOD JOIST SPAN TABLE

4.5

The joist span table below is for preliminary sizing of members only. It assumes that joists have simple spans. A rule of thumb for estimating joist spans: $\text{Span} = 24 \times \text{joist depth}$.

SIZE nominal	SPACING center to center	SPAN AS LIMITED BY DEFLECTION *			SPAN AS LIMITED BY BENDING			
		$E = 1,200,000 \text{ psi}$			$F_b = 1200 \text{ psi}$		$F_b = 1400 \text{ psi}$	
		Live load in lbs. per S.F.	40	60	40	60	40	60
2 x 6	12"		9'-8"	8'-7"	10'-11"	9'-5"	11'-9"	10'-2"
	16"		8'-10"	7'-10"	9'-6"	8'-2"	10'-3"	8'-10"
	24"		7'-9"	6'-10"	7'-10"	6'-8"	8'-5"	7'-3"
2 x 8	12		12-10	11-5	14-5	12-6	15-7	13-6
	16		11-8	10-5	12-7	10-10	13-7	11-9
	24		10-3	9-2	10-4	8-11	11-2	9-8
2 x 10	12		16-1	14-5	18-2	15-8	19-7	17-0
	16		14-9	13-2	15-10	13-8	17-2	14-9
	24		13-0	11-6	13-1	11-3	14-2	12-2
2 x 12	12		19-5	17-4	21-10	18-11	23-7	20-5
	16		17-9	15-10	19-1	16-6	20-8	17-10
	24		15-8	13-11	15-9	13-7	17-0	14-8
2 x 14	12		22-7	20-3	25-5	22-1	27-6	23-10
	16		20-9	18-7	22-4	19-3	24-1	20-10
	24		18-4	16-4	18-5	15-11	19-11	17-2

- * Joist deflection not to exceed $1/360$ th of span; stiffness of joist system under stress is more critical than its strength.
- Generally, if the overall construction depth is acceptable, deeper joists spaced further apart are more desirable for stiffness than shallow joists spaced more closely together.
- E = modulus of elasticity; F_b = allowable unit stress in extreme fiber bending; both vary according to species and of grade of lumber used.

BRIDGING

Bridging consists of wood or metal crossbracing or full-depth blocking between each joist at 8' intervals. Bridging may be required by some building codes if the joist depth is 6 or more times its thickness.

However, it is usually not necessary if the joist ends are supported laterally and their top compression edges are restrained by the subflooring.

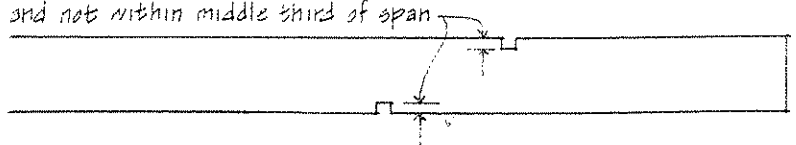
CUTS IN JOISTS

To allow plumbing and electrical lines to pass through floor joists, cuts may be made according to the following guidelines:

2" min. to joist edge

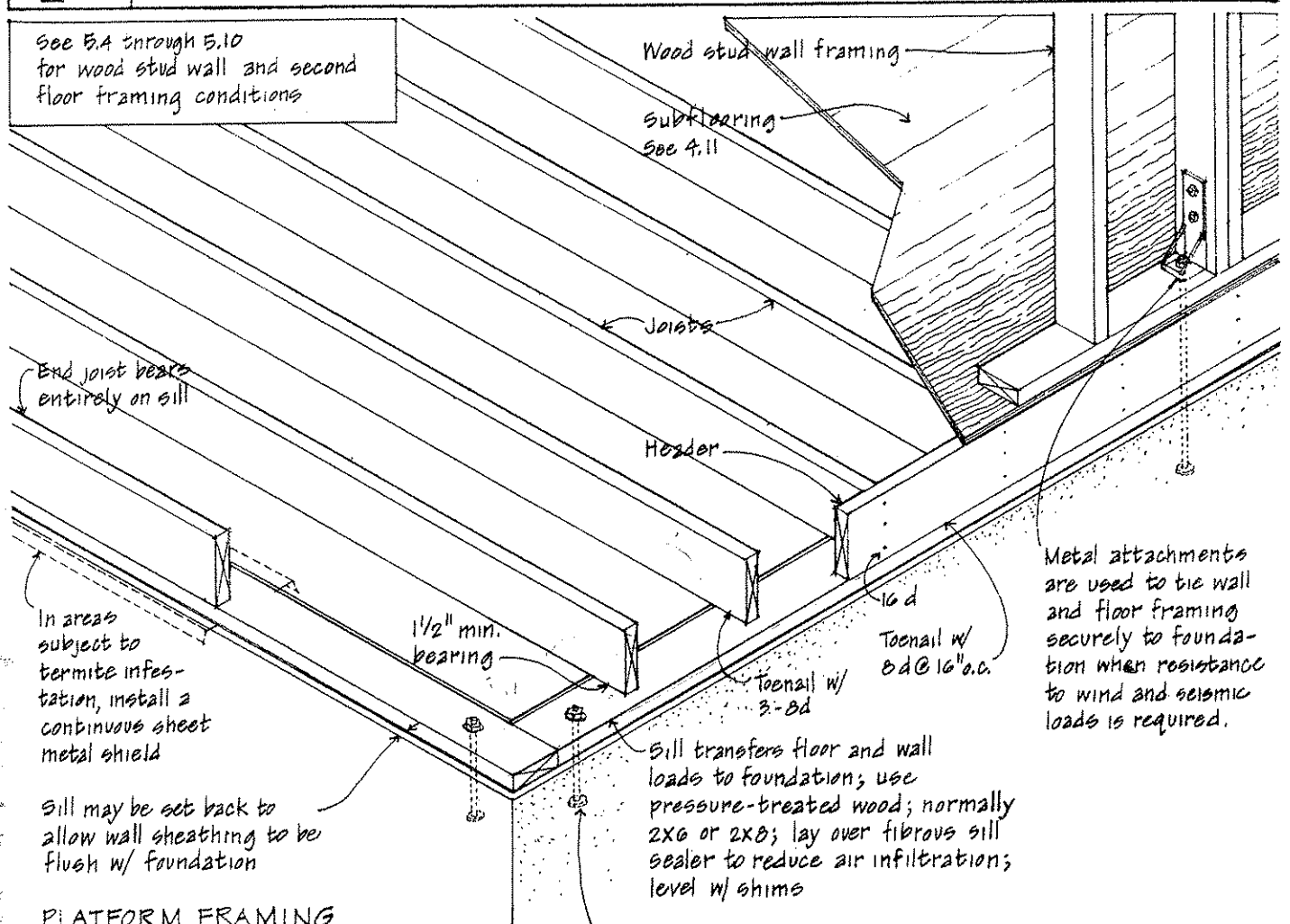
Max. diameter = $1/3$ joist depth

$1/6$ of joist depth maximum
and not within middle third of span

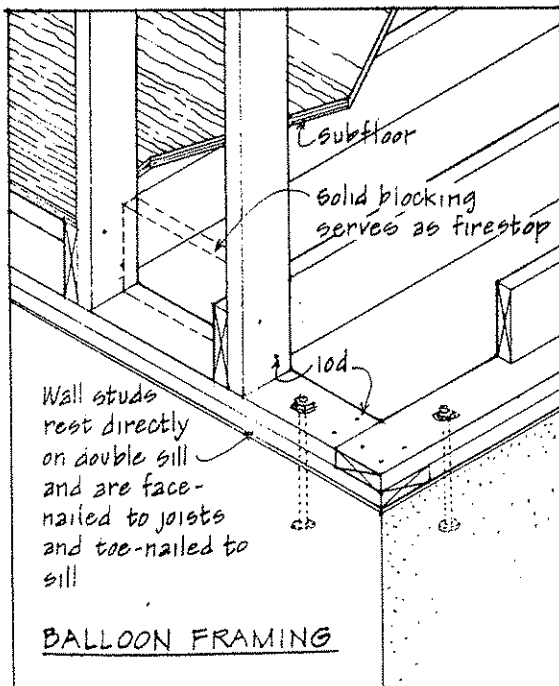


4.6 WOOD JOISTS: FOUNDATION SYSTEM CONNECTIONS

See 5.4 through 5.10 for wood stud wall and second floor framing conditions



PLATFORM FRAMING



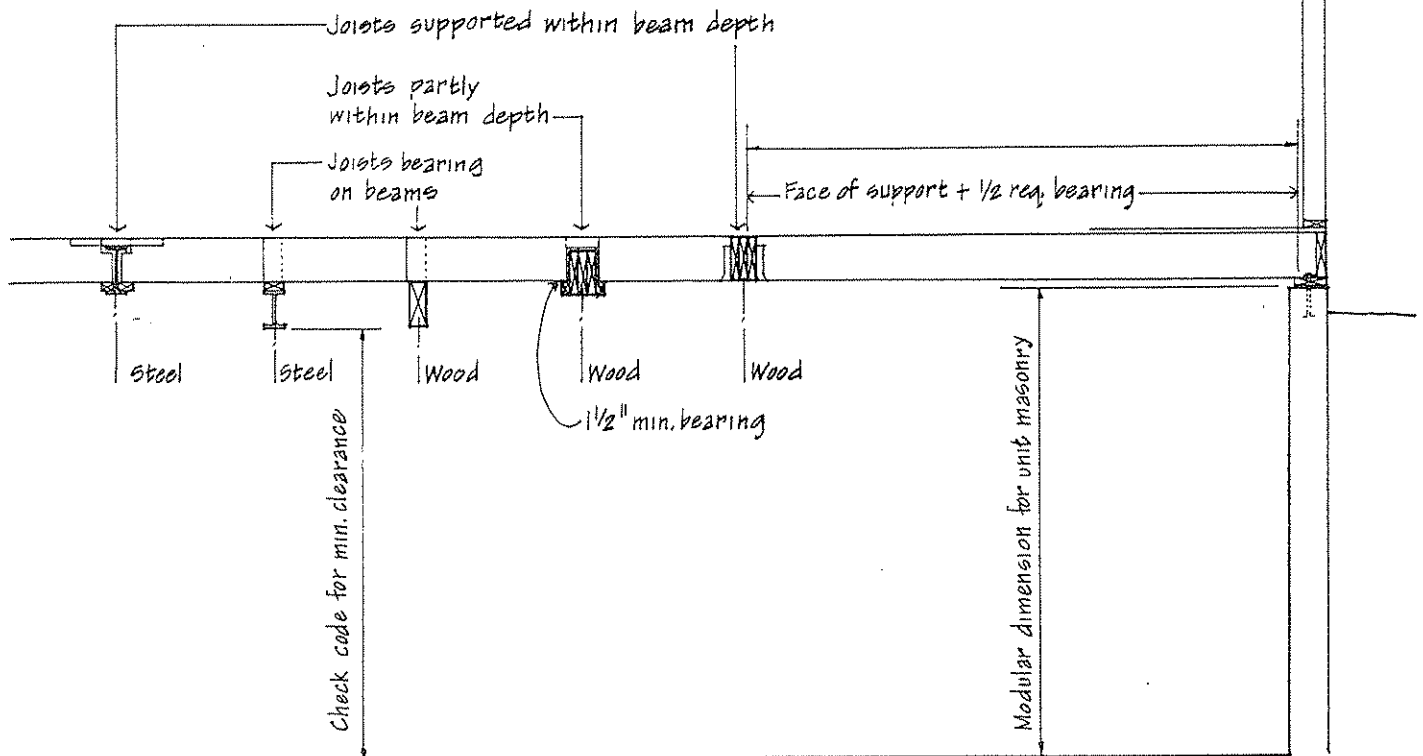
1/2" ϕ anchor bolts @ 6' o.c.; min. of 2 bolts per sill piece w/ one within 12" of each end

See 5.4 and 5.5 for discussion of balloon and platform framing.

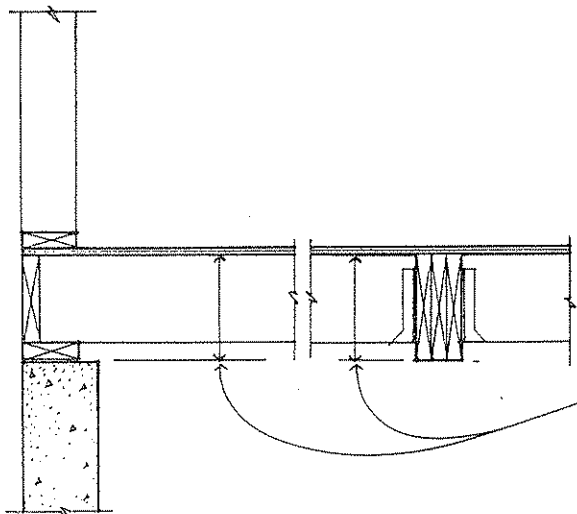
BALLOON FRAMING

WOOD JOISTS: BEAM SUPPORT CONDITIONS

4.7



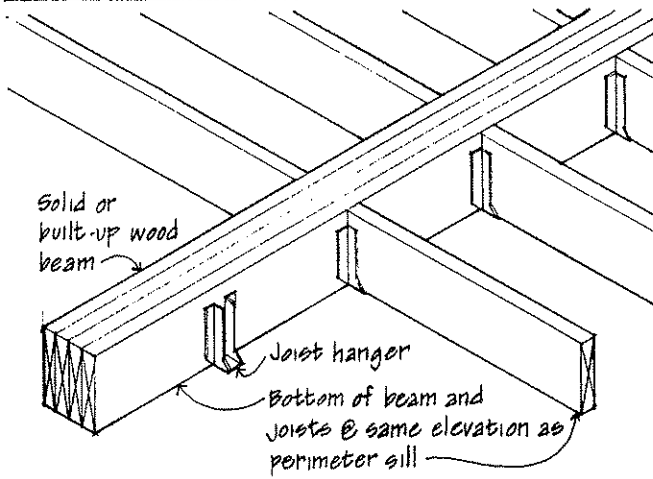
* See 4.13 for types of wood beams and beam span table



Wood joists may be supported by wood or steel beams. In either case, the height of the beam and its supports should be coordinated with both the perimeter sill condition and how the beam supports the floor joists. See next page for details of joist-beam connections.

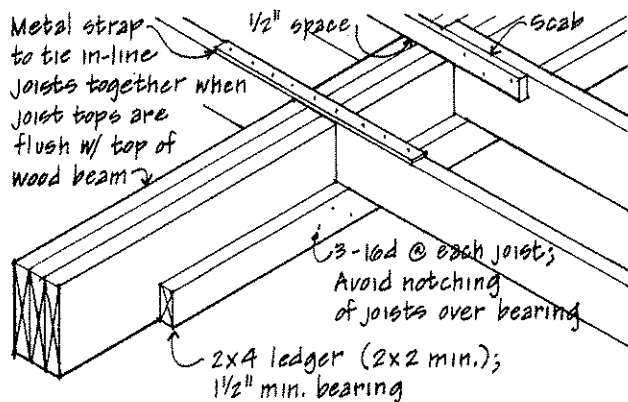
Wood is most susceptible to shrinkage perpendicular to its grain. For this reason, the total depth of wood construction for both the sill condition and the joist-beam connection should be equalized to avoid subsidence of the floor plane.

4.8 WOOD JOISTS: BEAM SUPPORT CONDITIONS

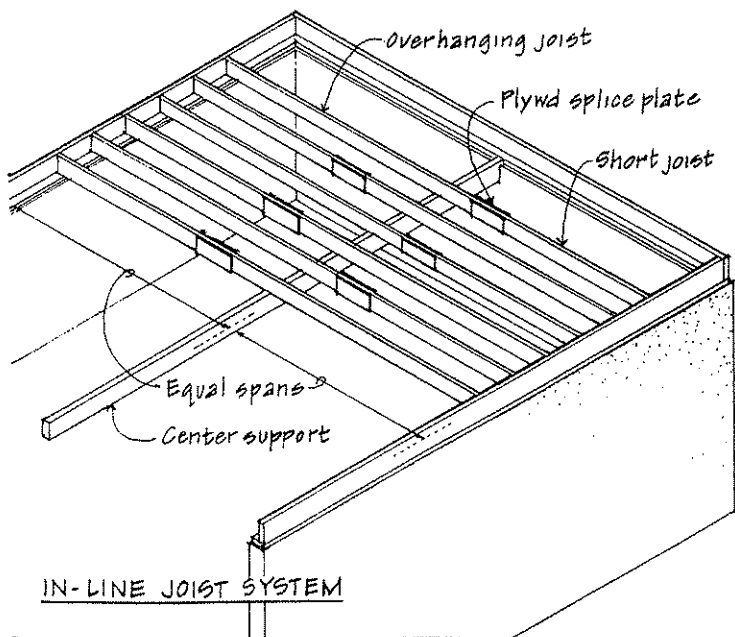


* Use only with well-seasoned lumber

TOP OF JOISTS FLUSH W/ BEAM



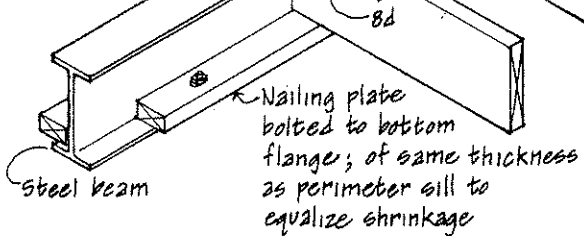
LEDGER BEARING



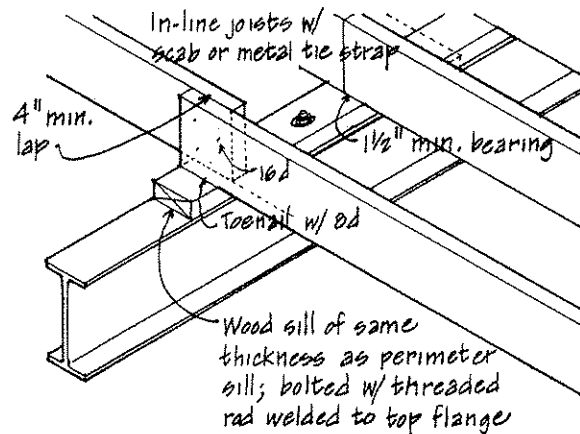
IN-LINE JOIST SYSTEM

Scab ties joists together, maintains horizontal continuity of floor structure, and supports subfloor

1/2" space to allow for joist shrinkage



LEDGER BEARING

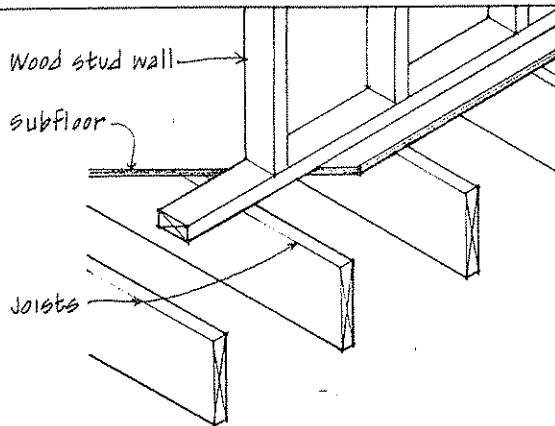


STEEL BEAM BEARING

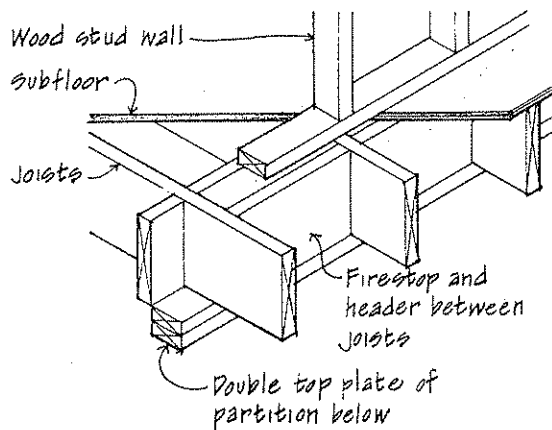
The in-line joist system allows the use of one size smaller joists that would normally be used in conventional framing. When used with studs and rafters spaced 24" o.c., in-line joists also make efficient use of 48" wide sheathing materials. These material savings, however, may be offset by increased labor costs.

The system consists of uneven length joists, the longer ones overhanging the center support 1/4 to 1/3 of the simple span, at a point where the bending moment approaches zero. The shorter joists are connected to the overhanging joists with shear-resisting metal connectors or plywood splice plates. The overhanging and short joists alternate sides and form joists continuous over two spans.

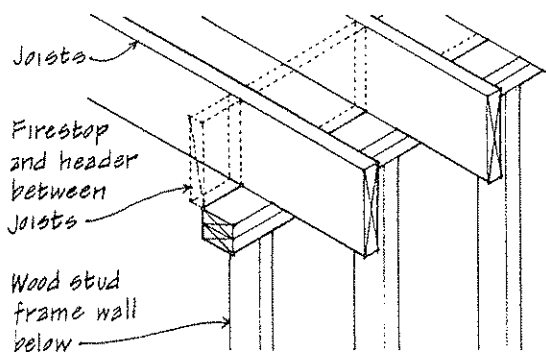
WOOD JOISTS: PARTITION CONNECTIONS



NON-BEARING PARTITION - No partition below

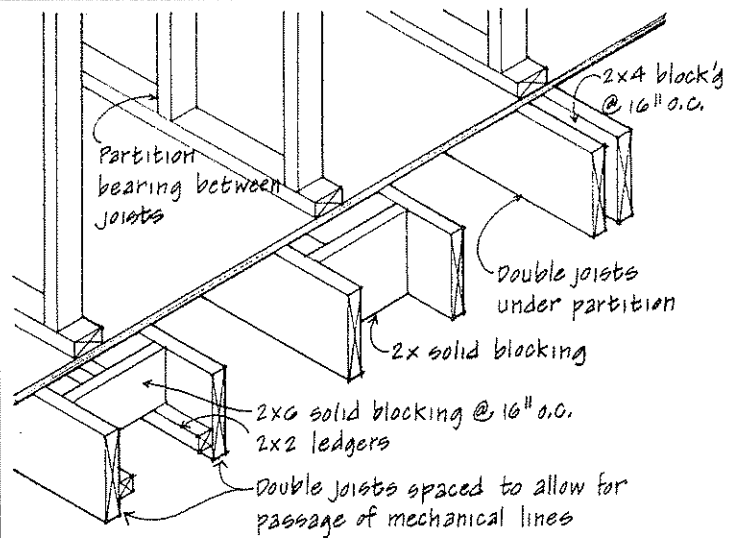


BEARING PARTITION

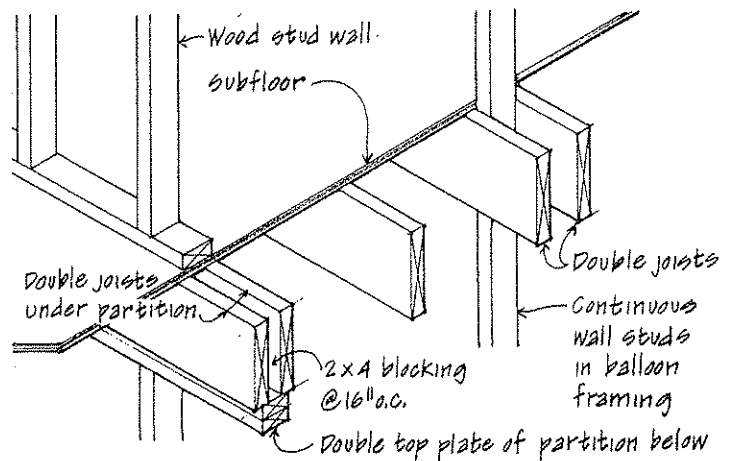


BEARING PARTITION - No partition above

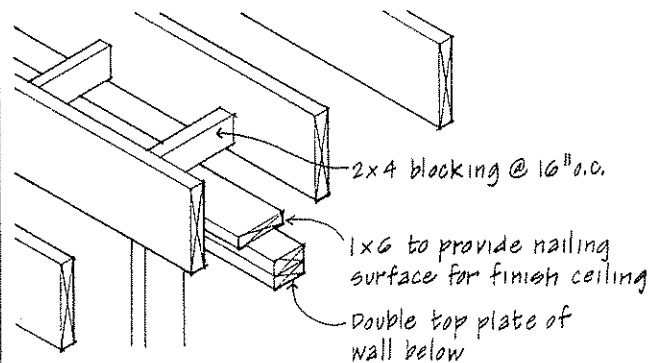
PARTITION PERPENDICULAR TO JOISTS



NON-BEARING PARTITION - No partition below



BEARING PARTITION

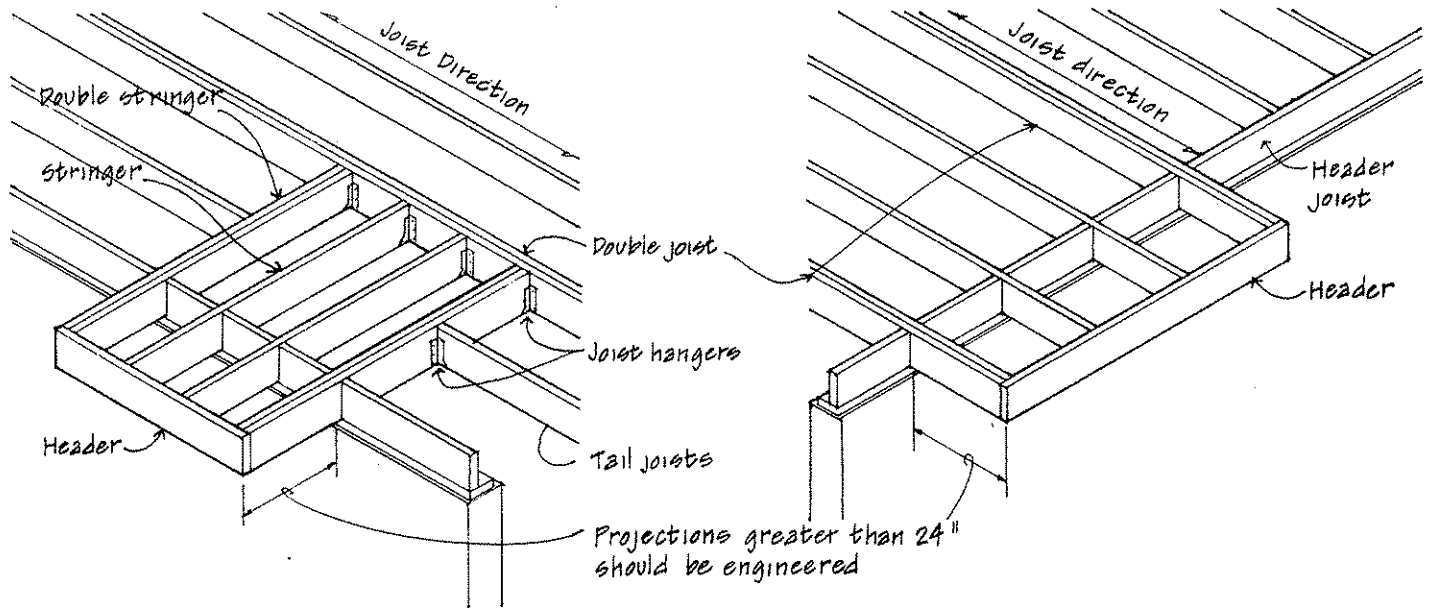


NON-BEARING PARTITION - No partition above

PARTITION PARALLEL TO JOISTS

4.10

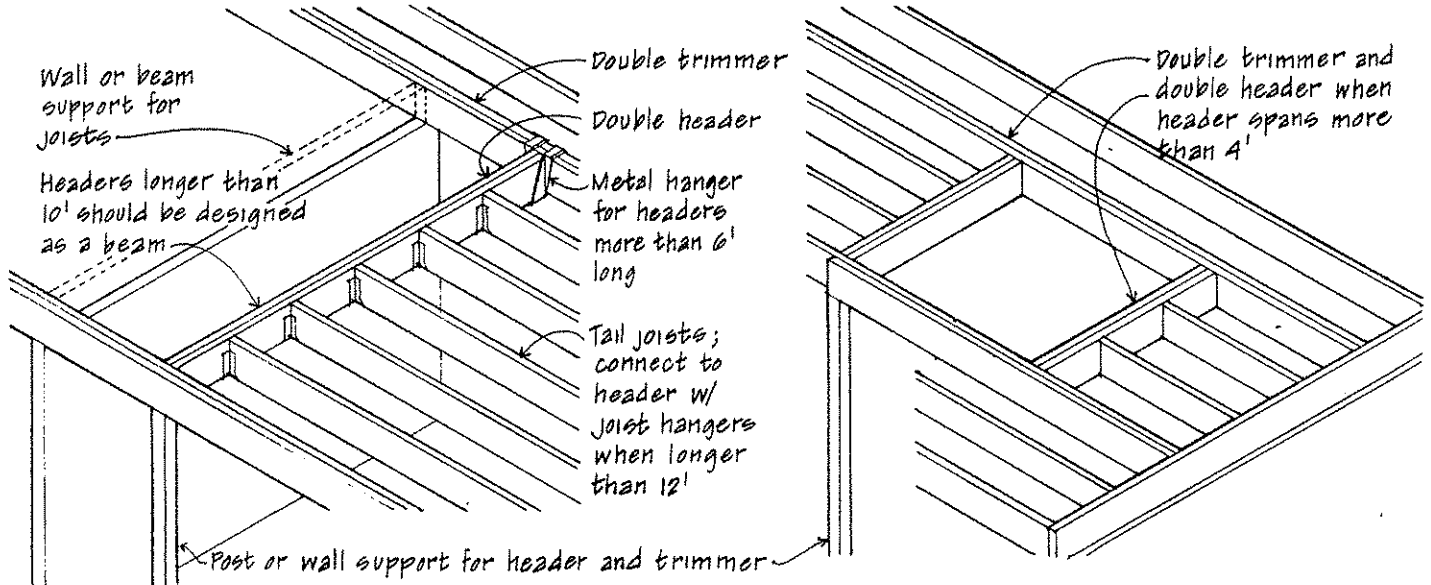
WOOD JOISTS: FLOOR PROJECTIONS AND OPENINGS



Projection perpendicular to joists

FLOOR PROJECTIONS

Projection parallel to joists



Length perpendicular to joists

FLOOR OPENINGS

Length parallel to joists

WOOD JOIST SUBFLOORING

4.11

Subflooring is the structural material that spans across floor joists, serves as a working platform during construction, and provides a base for the finish flooring. The joist and subfloor assembly can also be used as a diaphragm to resist horizontal forces if constructed according to approved standards. Consult the building code.

SUBFLOOR	THICKNESS (inch)	PANEL INDEX	SPAN (inches)
BOARDS			
1x4, 1x6	3/4	-	16
PANEL SUBFLOOR			
For rated sheathing & structural I & II grades	5/8 1/2-5/8 5/8-3/4, 7/8 3/4-7/8	32/16 36/16 42/20 48/24	16 16 20 24
UNDERLAYMENT			
Underlayment or C-C plugged (ext.) grades	1/4 3/8	Over panel subfloor Over board subfloor	
COMBINED SUBFLOOR- UNDERLAYMENT			
For APA rated sturd-1-floor grades	5/8 5/8-3/4 3/4-7/8, 1	16 20 24	16 20 24
2-4-1	1 1/8	48	48

Span rating is part of grade stamp found on back of panel; Span = max. joist spacing

Underlayment required before application of resilient flooring, carpet, or other non-structural flooring

Typically plywood, although other non-veneer panel materials such as oriented strand board (OSB), waterboard, and particle-board can be used if manufactured according to approved standards. Consult American Plywood Association (APA).

May be 24" if 25/32" wood strip flooring is laid perpendicular to joists

Underlayment provides impact load resistance and a smooth surface for the direct application of non-structural flooring materials; may be applied as a separate layer over board or panel subflooring, or be combined in a single thickness with the subfloor panel; when floor is subject to unusual moisture conditions, use panels with exterior glue (Exposure 1) or Exterior plywood.

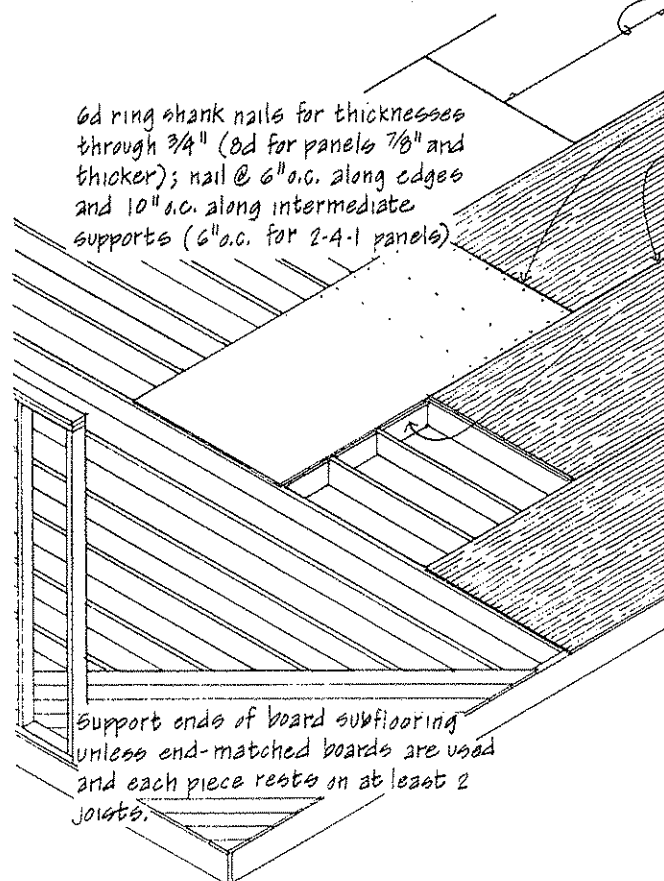
PANEL SUBFLOOR AND UNDERLAYMENT

Indicated spans assume panels are laid continuously over 2 or more spans with their long dimension perpendicular to the joists.

Stagger end joints.

Space joints 1/8" unless otherwise recommended by panel manufacturer; space butt joints in underlayment 1/32".

Provide blocking under edges or use tongue-and-groove panel edges; not required if underlayment joints are offset from subfloor joints.



6d ring shank nails for thicknesses through 3/4" (6d for panels 7/8" and thicker); nail @ 6" o.c. along edges and 10" o.c. along intermediate supports (6" o.c. for 2-4-1 panels)

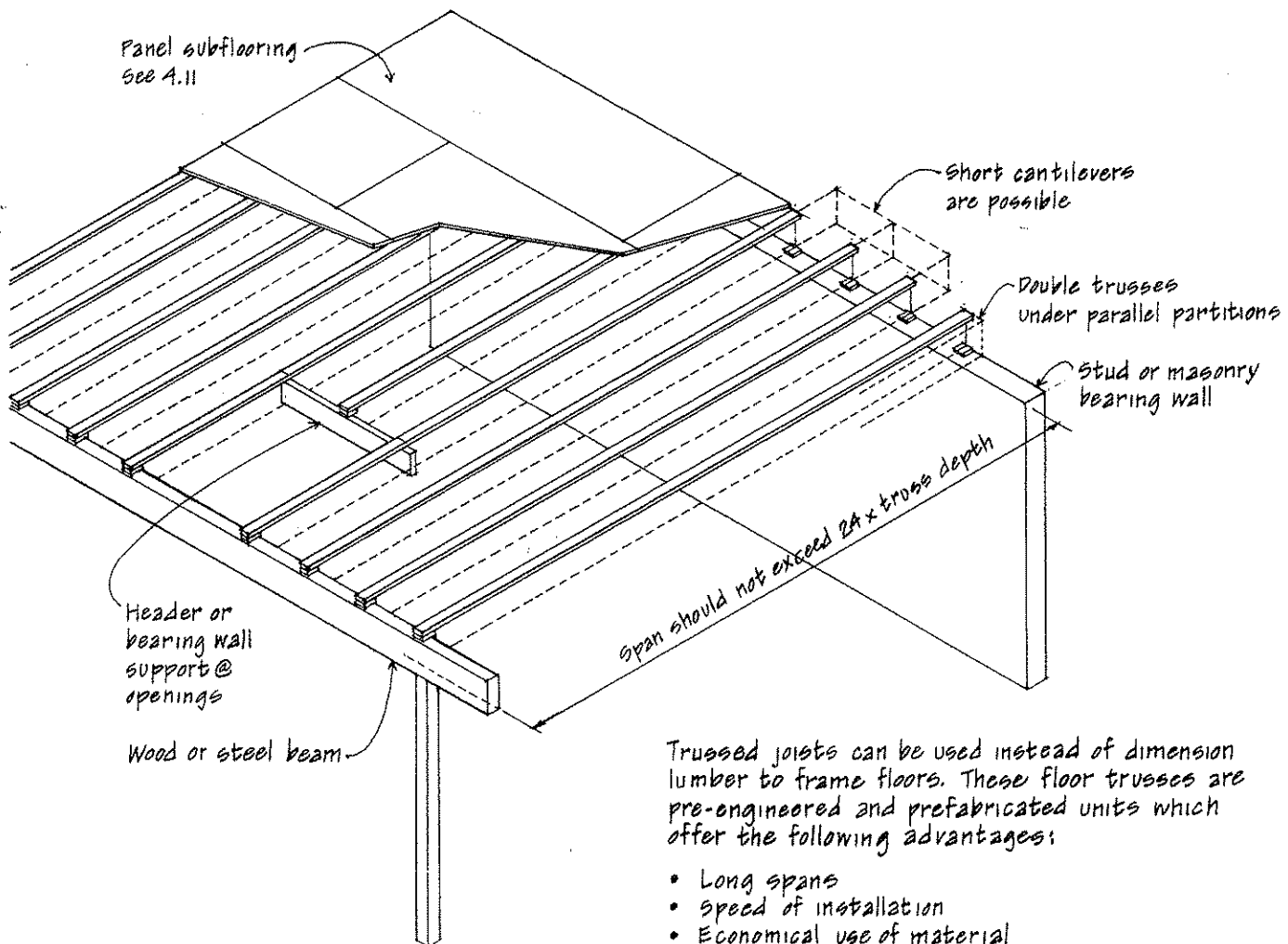
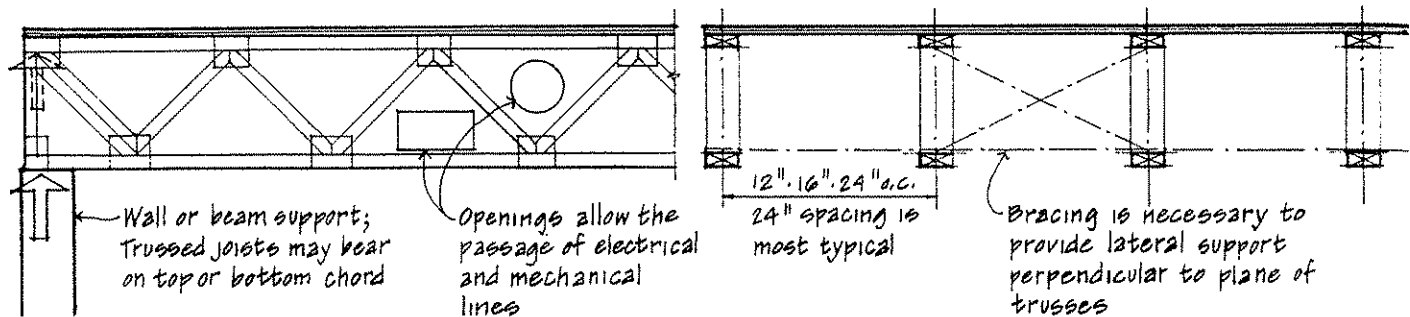
Support ends of board subflooring unless end-matched boards are used and each piece rests on at least 2 joists.

GLUED FLOOR SYSTEM

Gluing combined subfloor-underlayment panels to the floor joists enables the panels to act together with the joists to form integral T-beam units. This application system lessens floor creep and squeaking, and may increase floor stiffness and, in some cases, the allowable spans for the joists. These benefits, of course, are contingent on the quality of the application.

Panels are secured with power-driven fasteners or with 6d deformed shank nails @ 12" o.c. (6" o.c. for 2-4-1 panels). Consult APA for detail recommendations.

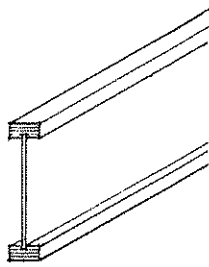
4.12 WOOD FLOOR TRUSSES



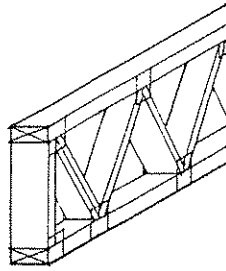
Trussed joists can be used instead of dimension lumber to frame floors. These floor trusses are pre-engineered and prefabricated units which offer the following advantages:

- Long spans
- Speed of installation
- Economical use of material

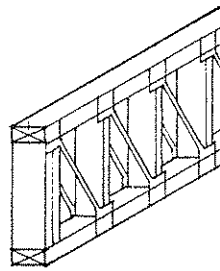
While the form of prefabricated floor trusses varies with the manufacturer, their layout is similar in principle to conventional wood joist framing.



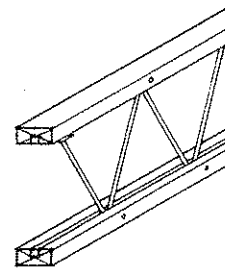
2x3 laminated flanges and $\frac{3}{8}$ " plywood web - small to medium spans



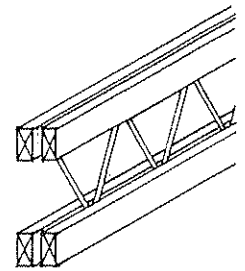
2x4 chords and webs w/ steel plate connectors - medium spans



Wood chords and verticals w/ steel webs - medium to long spans

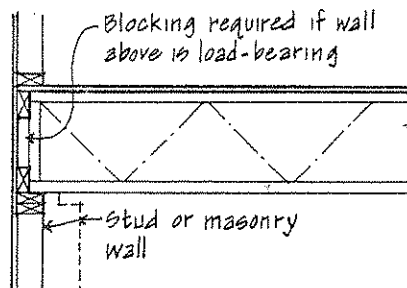


Wood chords w/ 1" to $1\frac{1}{2}$ " ϕ tubing webs - medium to long spans

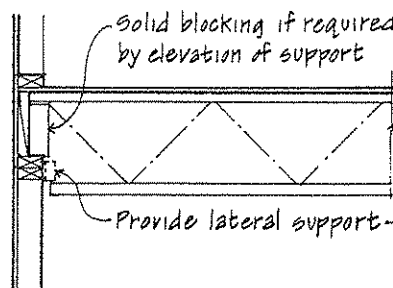


2-2x6 chords w/ $\frac{1}{2}$ " ϕ steel webs - long spans

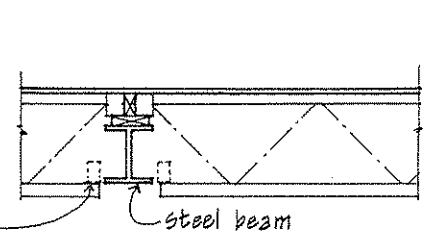
TYPES OF FABRICATED TRUSSED JOISTS



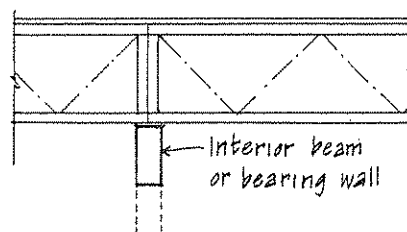
• Bottom chord bearing



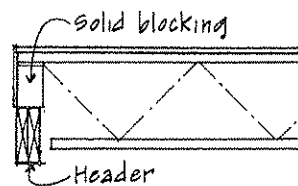
• Top chord bearing



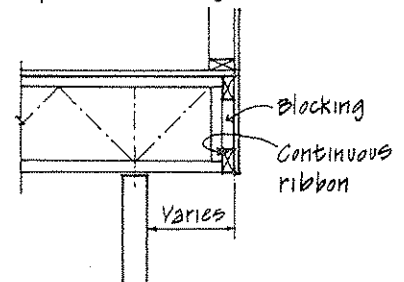
• Top chord bearing on steel beam



• Bottom chord bearing on interior



• Top chord bearing on header



• Bottom chord bearing @ cantilever

TYPICAL BEARING CONDITIONS

The floor truss span table to the right is to be used for preliminary design only. Spans should not exceed 24' x truss depth.

Consult manufacturer for sizes, spacing, allowable spans, bearing conditions, and truss specifications.

Live load	55 lbs. per S.F.			80 lbs. per S.F.		
	12" o.c.	16" o.c.	24" o.c.	12" o.c.	16" o.c.	24" o.c.
Spacing						
Depth						
12"	23'-4"	21'-0"	17'-0"	19'-0"	17'-4"	15'-0"
14"	26'-4"	22'-8"	18'-8"	21'-4"	19'-4"	16'-6"
16"	28'-6"	24'-8"	20'-0"	23'-6"	21'-4"	17'-8"
18"	30'-6"	26'-4"	21'-6"	25'-8"	23'-4"	19'-0"
20"	32'-4"	27'-8"	22'-8"	27'-8"	24'-8"	20'-4"
24"	35'-0"	30'-8"	25'-0"	31'-6"	27'-4"	22'-0"

4.14 WOOD PLANK AND BEAM FLOOR SYSTEM

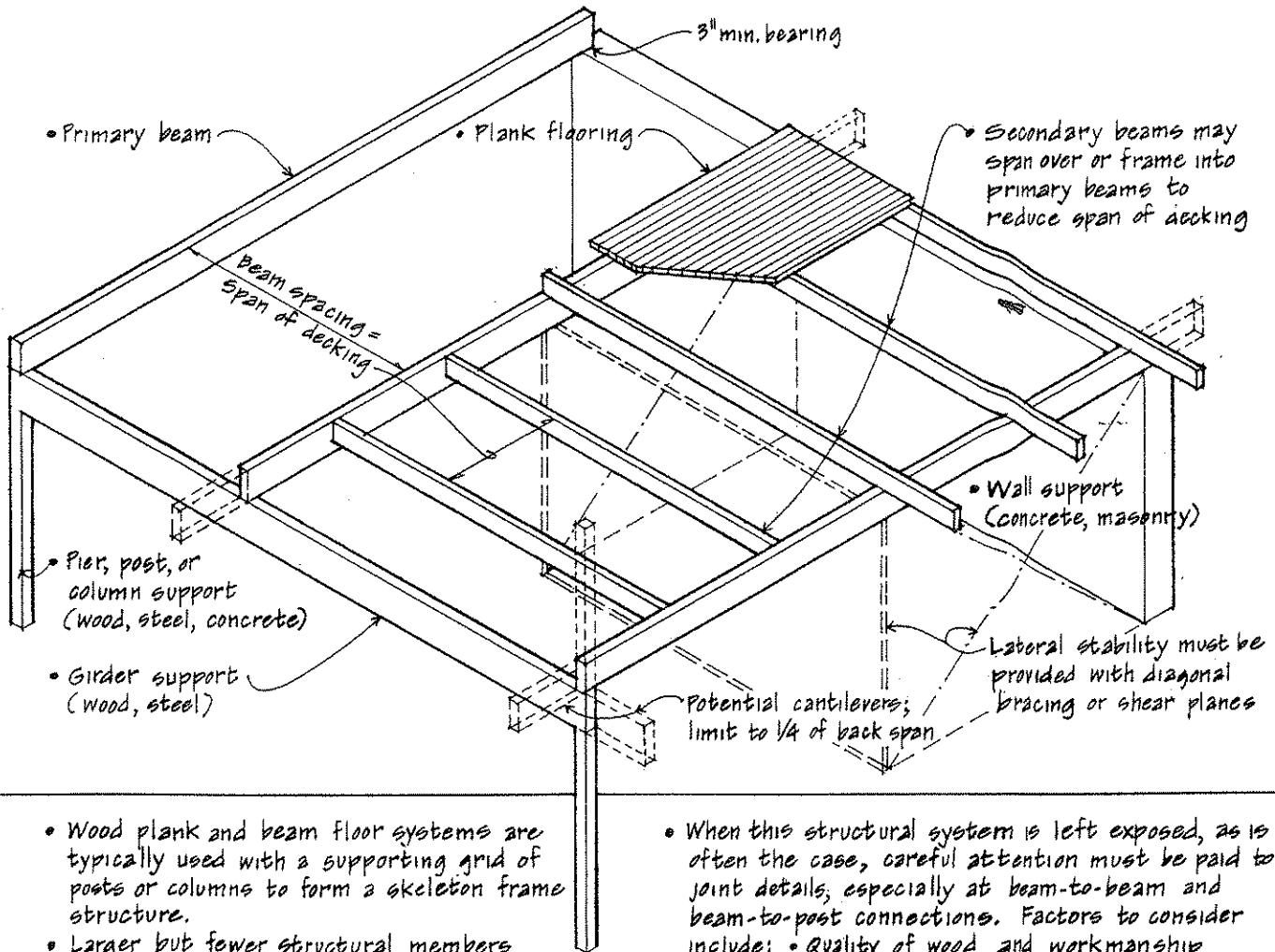
Structural floor plane of wood planks or decking; See 4.15-4.19
other options • 2-4-1 plywood

- prefabricated wood joist and plywood panels
- convention wood joist and panel subflooring construction

• Point support:
Pier, post or column

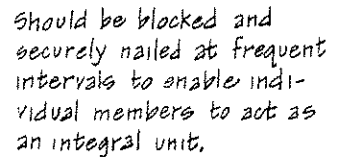
• Linear support:
Beam or girder

• Planar support:
Bearing wall



- Wood plank and beam floor systems are typically used with a supporting grid of posts or columns to form a skeleton frame structure.
- Larger but fewer structural members span greater distances with potential savings in material and labor costs
- Plank and beam framing is most effective when supporting moderate, evenly distributed loads; concentrated loads may require additional framing

- When this structural system is left exposed, as is often the case, careful attention must be paid to joint details, especially at beam-to-beam and beam-to-post connections. Factors to consider include:
 - Quality of wood and workmanship
 - Type of joints utilized
 - Means of fastening, whether exposed or concealed.
- Disadvantages of the plank and beam floor system include its susceptibility to impact sound transmission, and its inherent lack of concealed spaces for mechanical and electrical services except when spaced posts and beams are used.



More dimensionally stable than solid wood beam

Modulus of Elasticity (E) = 1.4×10^6 psi
(1.8×10^6 psi for glu-lam)

SOLID AND BUILT-UP WOOD BEAMS			GLUE-LAMINATED BEAMS		
SPAN Feet	SPACING Feet	SIZE Nominal in inches	SPAN Feet	SPACING Feet	SIZE Actual in inches
10	4	2 × 2 × 8	12	6	3 1/8 × 9
	6	2 × 2 × 10		8	3 1/8 × 10 1/2
	8	4 × 10		10	3 1/8 × 10 1/2
12	4	3 × 10		12	3 1/8 × 12
	6	2 × 2 × 12	16	6	3 1/8 × 13 1/2
	8	4 × 12		8	3 1/8 × 15
14	4	4 × 10		10	3 1/8 × 15
	6	6 × 10	12	3 1/8 × 15	
	8	3 × 2 × 12	20	6	3 1/8 × 16 1/2
16	6	3 × 2 × 12		8	5 1/8 × 15
	8	4 × 2 × 12		10	5 1/8 × 18
	18	6		6 × 12	12
8		8 × 12	24	6	5 1/8 × 16 1/2
20		6		2 × 3 × 14	8
	8	2 × 4 × 14		10	5 1/8 × 21
	20	6	20	12	5 1/8 × 22 1/2
8		6		5 1/8 × 19 1/2	
32		8		5 1/8 × 21	
		10		5 1/8 × 24	
	12	5 1/8 × 25 1/2			
20	6	32	6	5 1/8 × 21	
	8		5 1/8 × 24		
	10		5 1/8 × 27		
	12		6 3/4 × 27		

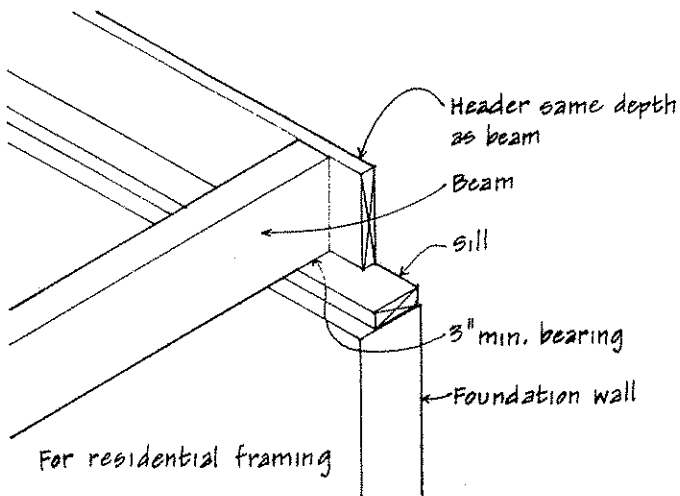
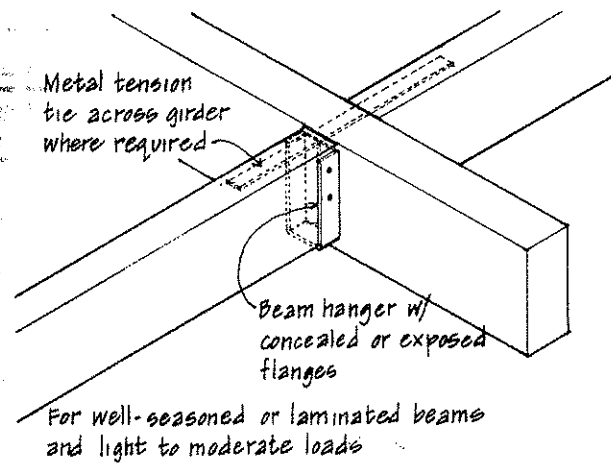
These tables assume the following:

Total live load = 40 lbs. per S.F.

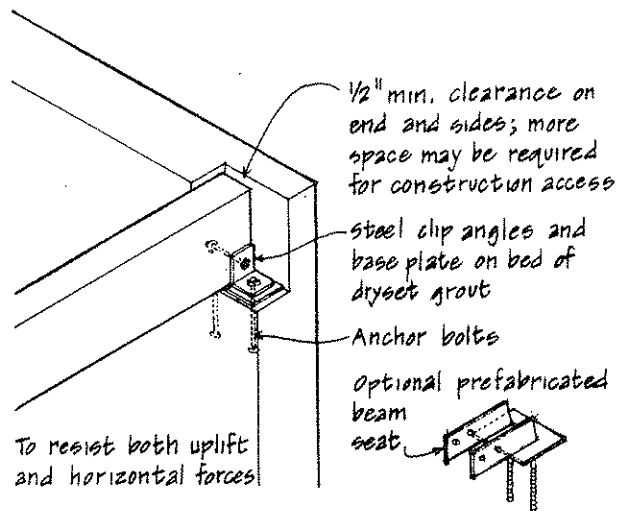
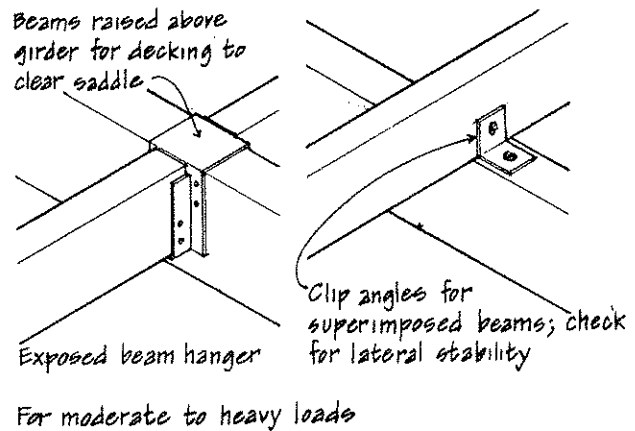
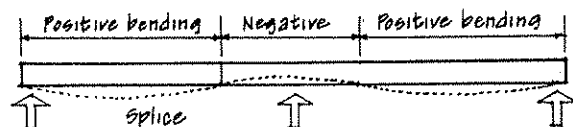
Allowable deflection = 1/360 of span

Extreme fiber stress in bending (F_b) = 1200 psi
(2400 psi for glu-lam) →

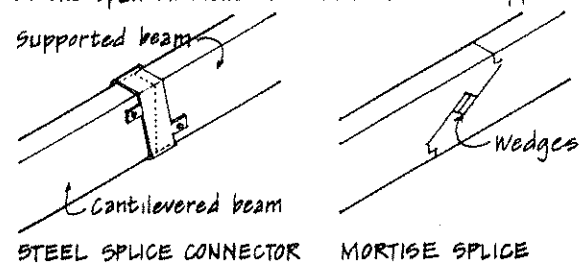
Modulus of Elasticity (E) = 1.4 × 10⁶ psi
(1.8 × 10⁶ psi for glu-lam) →

FOUNDATION WALL SUPPORTGIRDER SUPPORT

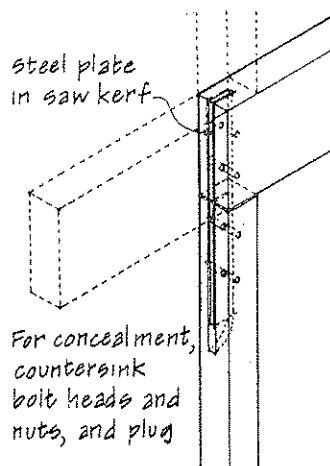
A variety of metal attachments are manufactured for wood-to-wood, wood-to-metal, and wood-to-masonry connections. These include joist and beam hangers, post bases and caps, framing angles and anchors, and floor ties and holdowns. Consult manufacturer for specific sizes, configurations, allowable loads, and fastening requirements. Depending on the magnitude of the loads being resisted or transferred, the connectors may be nailed or bolted.

MASONRY OR CONCRETE WALL SUPPORTGIRDER SUPPORT

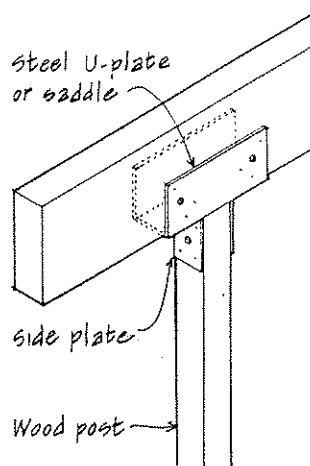
Continuous spans produce more uniform stresses than simple spans, resulting in more efficient use of material. Any splices should occur at points of minimum bending stress, approximately 1/4 to 1/3 of the span on either side of an interior support.



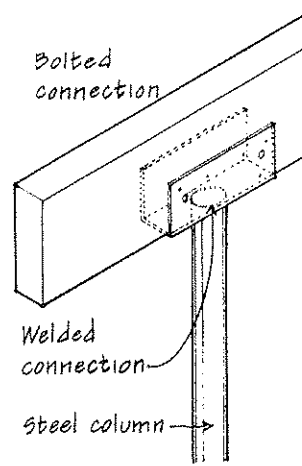
WOOD BEAMS: BEAM-COLUMN CONNECTIONS



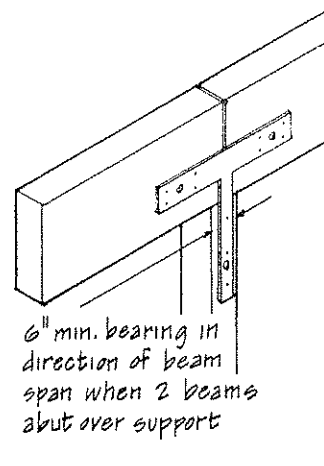
• Concealed connection



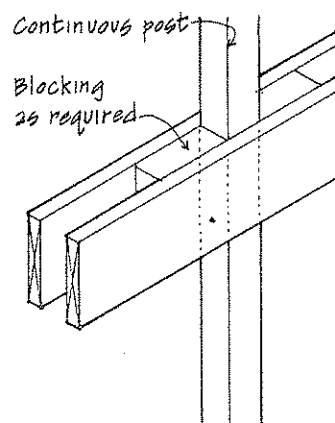
• Exposed column cap



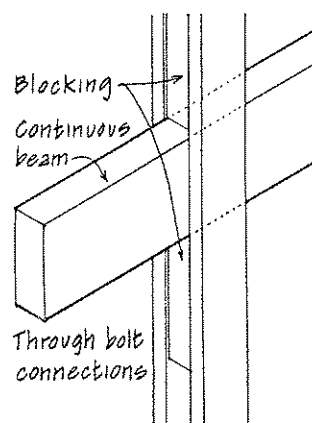
• Exposed column cap



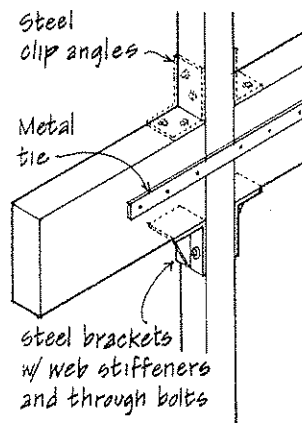
• Exposed T-strap

POST OR COLUMN CONNECTIONS

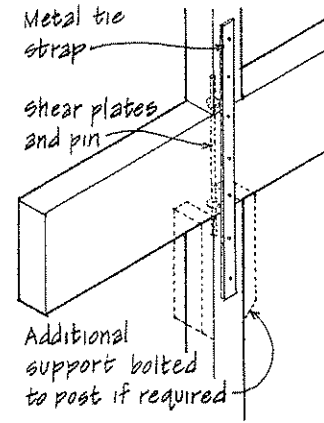
• Spaced beam-solid post



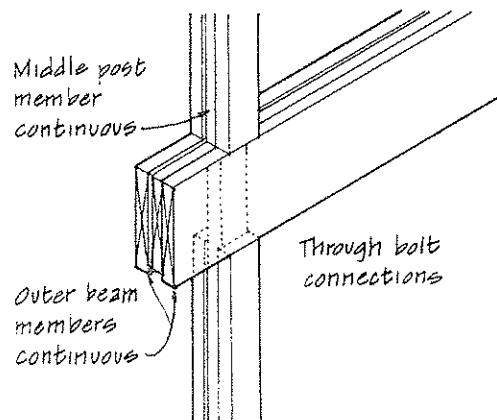
• Solid beam-spaced post



• Post continuous



• Beam continuous

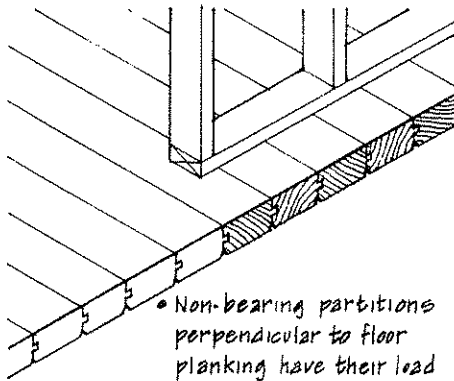
POST OR COLUMN CONNECTIONS: Columns continuing verticallyINTERLOCKING POST AND BEAM

The size and number of bolts required at a connection depend on the thickness of the members, the species of wood, the magnitude and direction of the load relative to the grain of the wood, and the use of metal connectors. See 5.15 for bolt spacing guidelines.

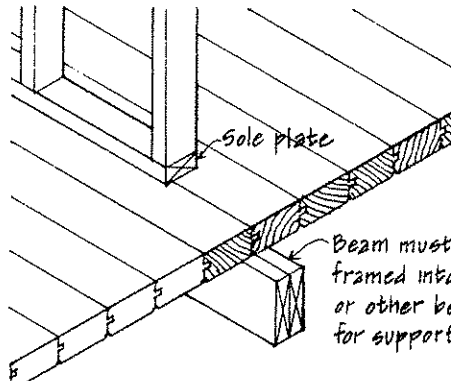
When there is insufficient area to accommodate the required number of bolts, shear plate or split ring connectors, which can develop greater stresses per unit bearing, can be used.

4.18

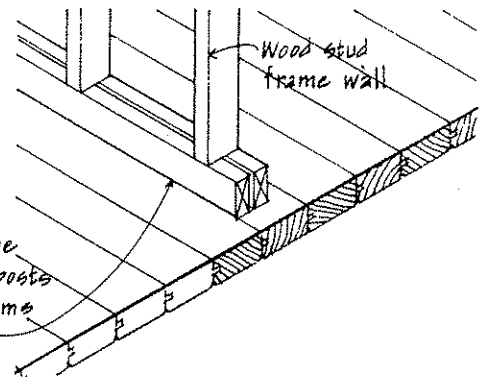
WOOD PLANK AND BEAM: PARTITION CONNECTIONS



- Non-bearing partitions perpendicular to floor planking have their load distributed evenly across the planks



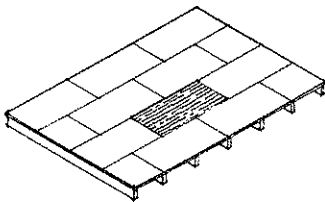
- Partitions parallel to floor planking may be supported by beams either below or above the planking

NON-BEARING PARTITIONS OVER WOOD PLANK FLOOR

In the plank and beam framing system, the beam grid layout should be carefully integrated with the required placement of interior partitions for both structural and visual reasons. Normally, most partitions in this system are non-bearing and may be placed as shown above. If bearing partitions are required, however, they should continue down to a foundation wall or be placed over floor beams large enough to carry the additional load.

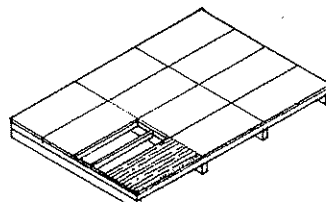
FLOOR SYSTEMS SPANNING BETWEEN BEAMS

Other than the conventional wood joist and panel subfloor system, the following can be utilized:



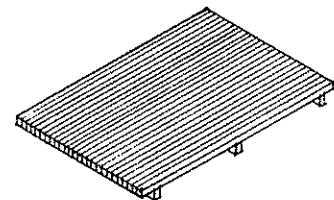
2-4-1 Plywood
(combined subfloor-underlayment)

- 1/8" thick
- Can span up to 4'
- Tongue and groove edges
- Laid continuously over 2 spans with face plies perpendicular to beams and end joints staggered
- No overhang possible
- See 4.11



Prefabricated panels

- Plywood sheathing over nominal 2" framing which acts as floor joists
- Glue-nailed or bonded with adhesives under heat and pressure to form stressed skin panels
- Insulation, vapor barrier, and interior finish may be applied at one time
- Limited overhang possible

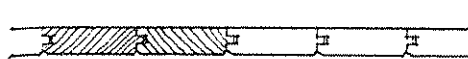


Wood planking

- See facing page
- Limited overhang possible
- Openings and concentrated loads require additional framing
- Wood strip flooring laid at right angles to planking
- Underlayment required for resilient and thinset tile flooring

WOOD PLANK FLOORING

4.19



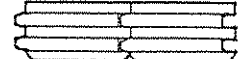
Solid
Nominal 2x6, 2x8



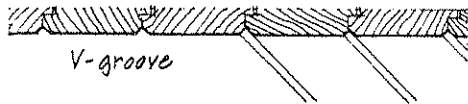
Solid
Nominal 3x6, 4x6



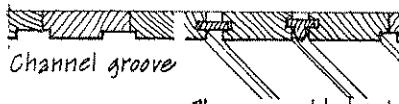
Laminated
Nominal 3x6, 8, 10; 4x6, 8; 5x6, 8



TYPES OF WOOD DECKING



V-groove



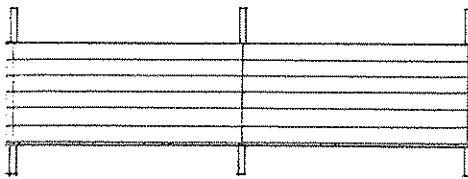
Channel groove



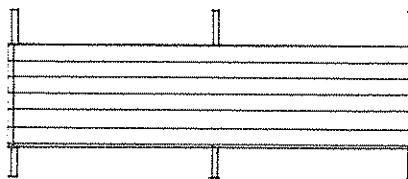
Striated

SURFACE PATTERNS for exposed plank ceilings

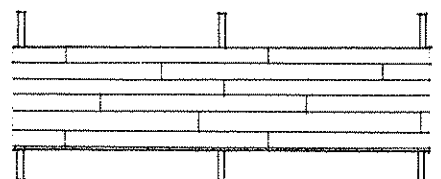
Plain or molded spline



Simple span



Double span



Continuous span over 4 or more supports; use of random lengths reduces waste; layout must be carefully controlled.

Planks simply supported at each end have the most deflection for a given load.

Structurally, the most efficient use of material of a given length.

TYPES OF DECKING SPANS

- Distance between end joints in adjacent courses must be at least 2'
- Joints in the same general line must rest on at least one support
- Joints in non-adjacent rows must be separated by 12" or 2 rows of planks
- Only one joint should occur in each course between supports
- Each plank must rest on at least one support
- In end spans, one-third of the planks should be free of joints.

TOTAL ALLOWABLE UNIFORMLY DISTRIBUTED LOADS *			
Nominal deck thickness in inches	Span feet	Simple span lbs. per S.F.	Controlled random layup lbs. per S.F.
2	6	46	
	8	20	25
3	8	62	106
	10	32	54
	12	18	31
3 (superthick)	10	53	90
	12	31	52
	14	19	33
4	12	44	74
	14	28	47
	16	19	31
5	14	51	86
	16	34	58
	18	24	41
	20	18	30

The above assumes: Fiber stress in bending (F_b) = 1500 psi
Modulus of elasticity (E) = 1.3×10^6 psi
Allowable deflection = $1/240$ of decking span

* This table is to be used for preliminary sizing only. Consult manufacturer's literature.

4.20 STRUCTURAL STEEL FRAMING

Beam framing may be spanned with:

- Steel floor decking w/ concrete slab; see 4.27
- Sitecast or precast concrete

Primary beam or girder

Secondary beams

Beams may be:

- Beam supported
- Column supported
- Wall supported

For non-bearing or curtain wall options, see 5.

Structural steel elements are used to construct a skeleton frame similar to wood post-and-beam construction. Structural steel, however, is flexible enough to frame both low-rise buildings and tall structures.

- Since structural steel is difficult to work on-site, it is normally cut, shaped and drilled in a fabrication shop according to the designer's specifications; this can result in relatively fast, precise construction.
- Because steel can lose strength rapidly in a fire, fire-resistant assemblies or coatings are required; in exposed conditions, corrosion-resistance is also required.
- Steel framing is most efficient when it is laid out along a regular grid.
- To resist lateral wind or earthquake forces, shear planes, diagonal bracing, or rigid frames with moment-resisting connections can be used.

Column or beam support:

Connections usually use transitional elements, such as angles, tees, or plates; may be riveted, but more often bolted and/or welded.

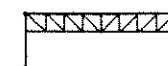
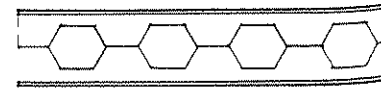
Wall support:

Steel bearing plates are required to distribute the concentrated load imposed by the beam so that the resultant unit bearing pressure does not exceed the allowable for the wall material.

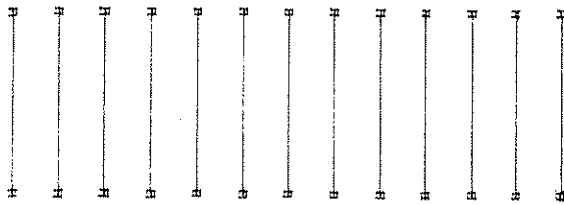
I-beam (S) shapes have been largely superseded by the more structurally efficient wide-flange (W) shapes. Beams may also be in the form of channel (C) sections, structural tubing, or composite sections.

For column shapes and wall framing, see 5.38 and 5.40.

Steel base plates are required to distribute concentrated column loads to their concrete foundations. See 5.38.



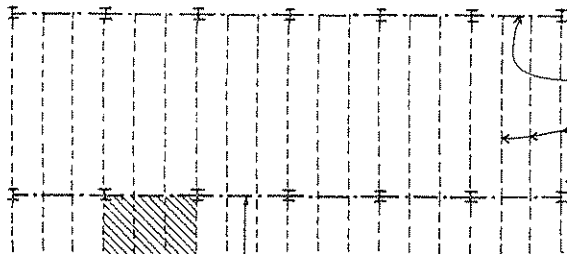
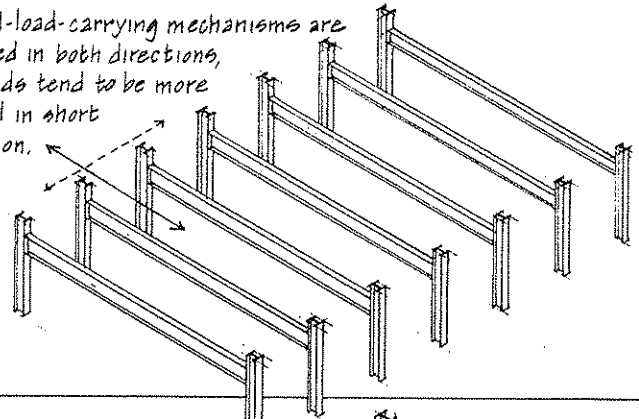
STEEL FLOOR FRAMING SYSTEMS



Each pair of closely-spaced external columns supports a long-span beam. This system is suitable for long, narrow buildings, especially when a column-free space is desired.

ONE-WAY BEAM SYSTEM

Lateral-load-carrying mechanisms are required in both directions, but loads tend to be more critical in short direction.



Typical span range for beams is 20'-60'; for spans beyond 32', open-web steel joists are an economical alternative

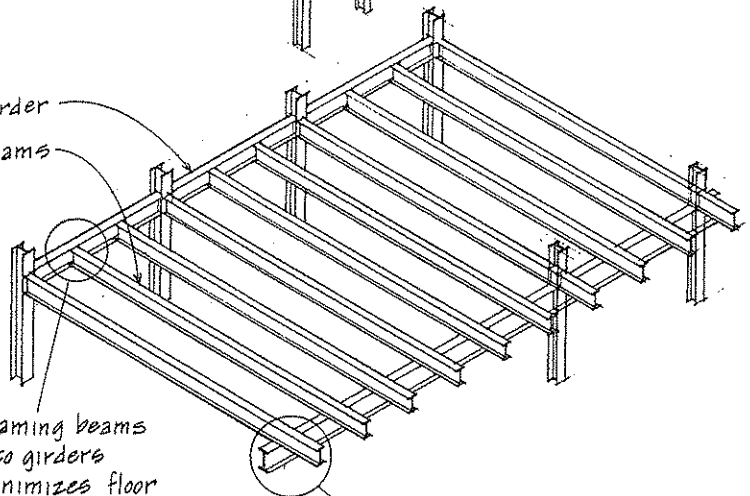
6' to 15' beam spacing, depending on floor deck

Generally, steel framing should utilize rectangular bay units, with comparatively lightly loaded beams spanning further than more heavily loaded girders.

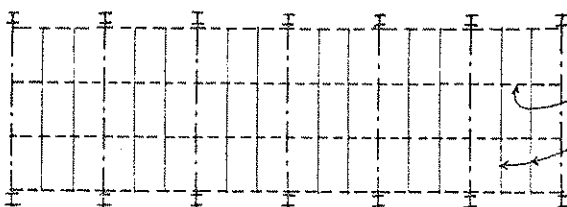
Girder
Beams

Framing beams into girders minimizes floor depth; some mechanical services can pass through holes cut into the beam webs, but large lines may have to be accommodated in space below.

2-layer system increases floor depth considerably but provides more space for mechanical services.



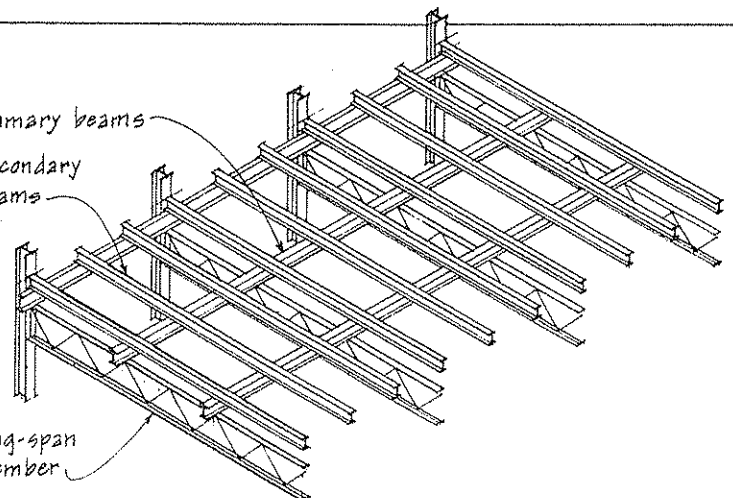
TWO-WAY BEAM SYSTEM



When a large, column-free space is required, long-spanning plate girders or trusses can be used to carry the primary beams which, in turn, support a layer of secondary beams.

Primary beams
Secondary beams

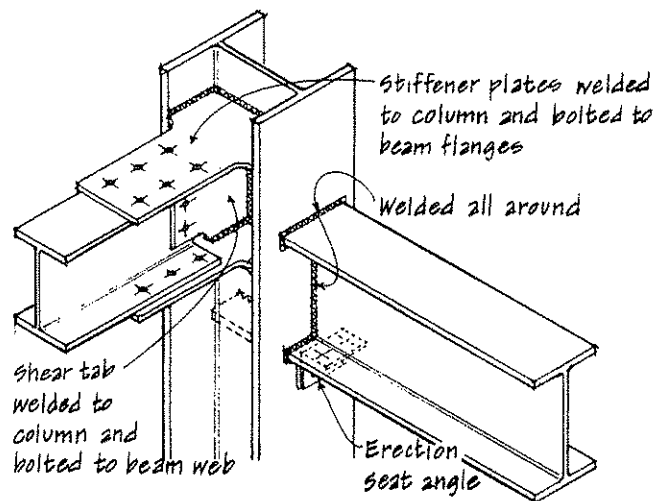
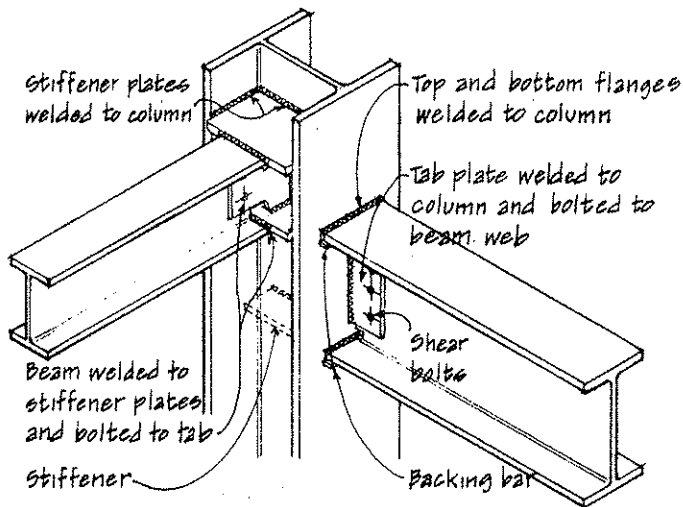
Long-span member



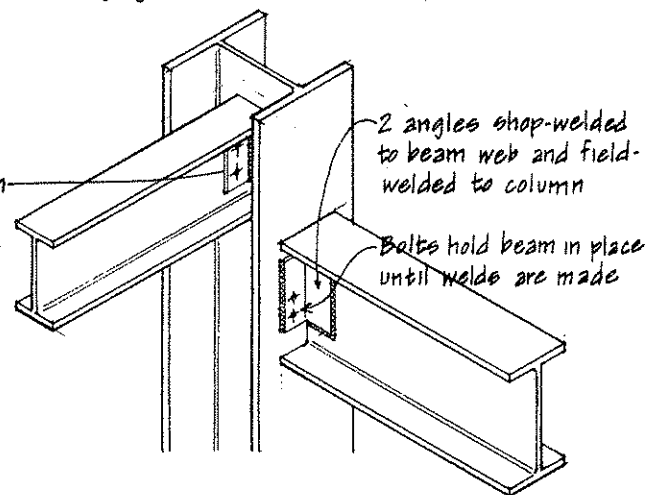
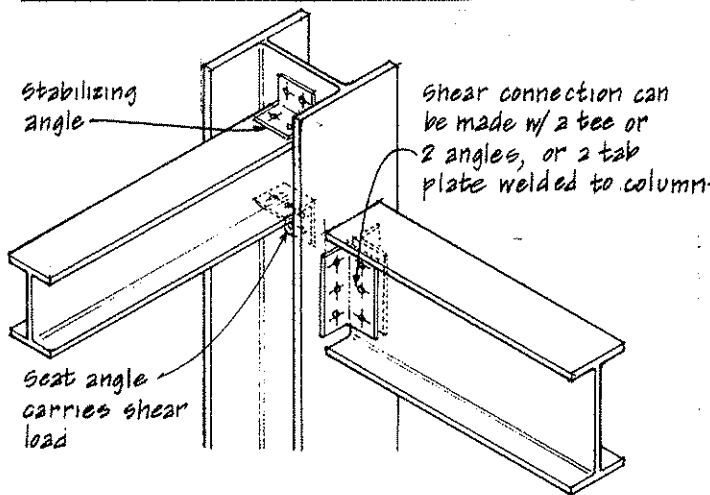
TRIPLE BEAM SYSTEM

4.22

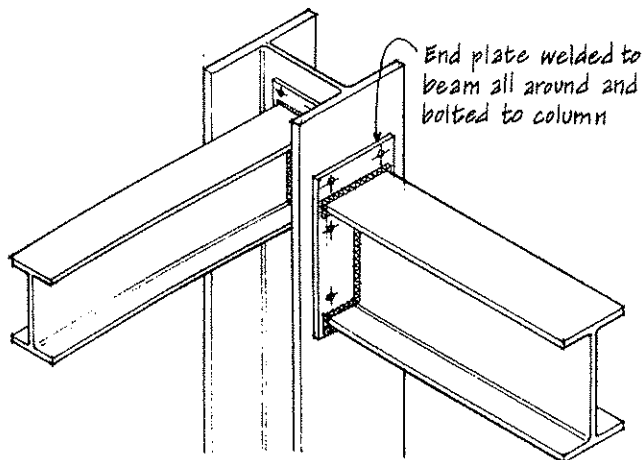
STEEL BEAM • COLUMN CONNECTIONS



TYPE 1: MOMENT CONNECTIONS - Beam flanges must be rigidly connected to column



TYPE 2: SHEAR CONNECTIONS



TYPE 3: SEMI-RIGID CONNECTION

The strength of a connection depends on the sizes of the members and the connecting tees, angles, or plates, as well as the configuration of bolts and/or welds used. The American Institute of Steel Construction (AISC) defines three types of steel framing which govern the size of members and the types of their connections:

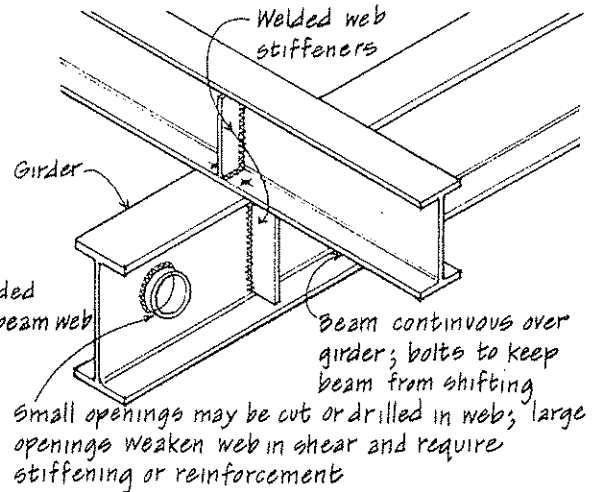
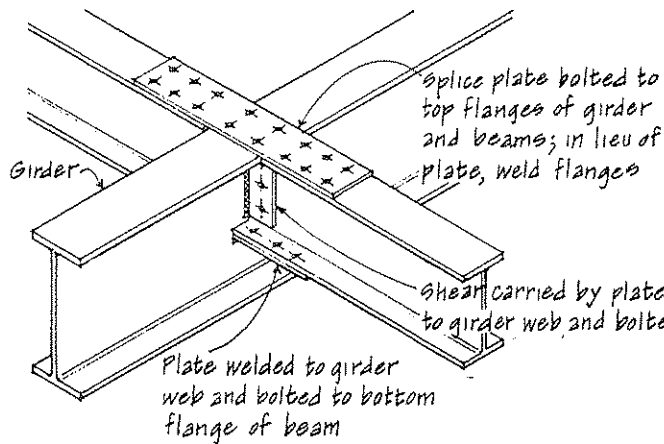
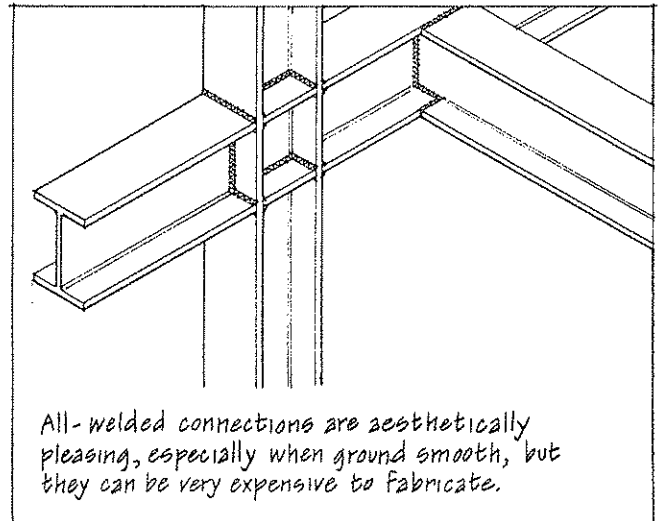
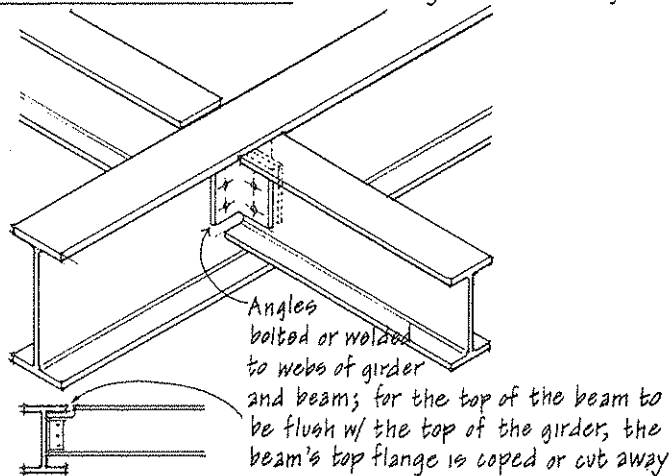
Type 1, rigid framing, assumes that beam-column connections are rigid and will be able to hold their original angles under loading.

Type 2, simple framing, assumes the ends of beams and girders are connected for shear only and are free to rotate under gravity loads.

Type 3, semi-rigid framing, assumes beam and girder connections possess a limited but known moment-resisting capacity.

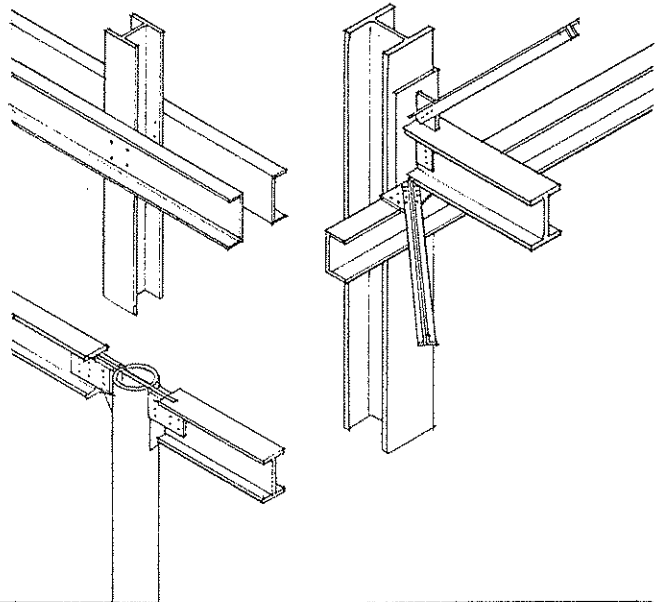
STEEL BEAM • GIRDER CONNECTIONS

4.25

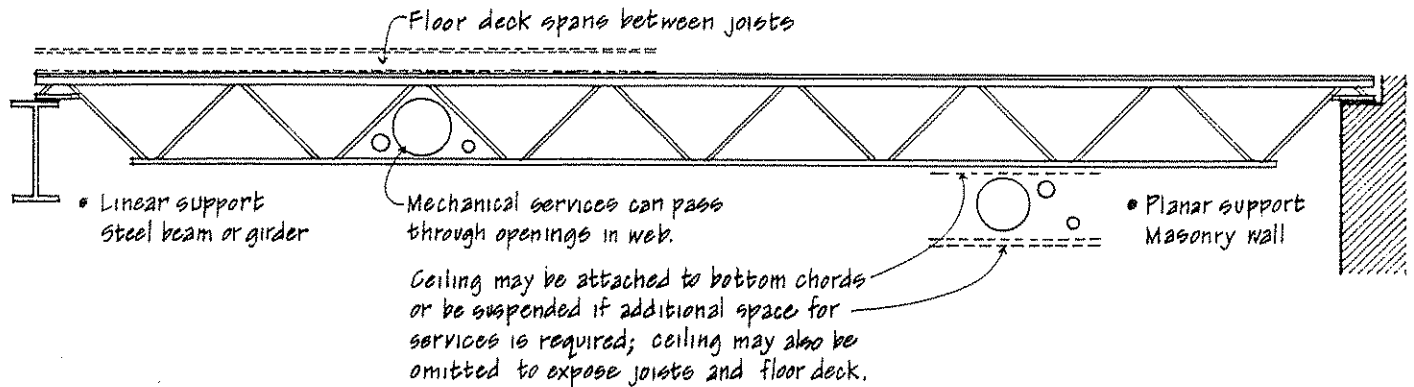
MOMENT CONNECTIONS - Continuity in beam flanges is requiredSHEAR CONNECTION

There are many ways in which steel connections can be made, using different types of connectors and various combinations of bolts and welds. Refer the AISC Manual of Steel Construction for steel section properties and dimensions, allowable load tables for beams and columns, and requirements for welded and bolted connections.

In addition to strength and degree of rigidity, connections should be evaluated for economy of fabrication and erection, and for visual appearance if the structure is exposed to view.



4.24 OPEN WEB JOIST FLOOR SYSTEM

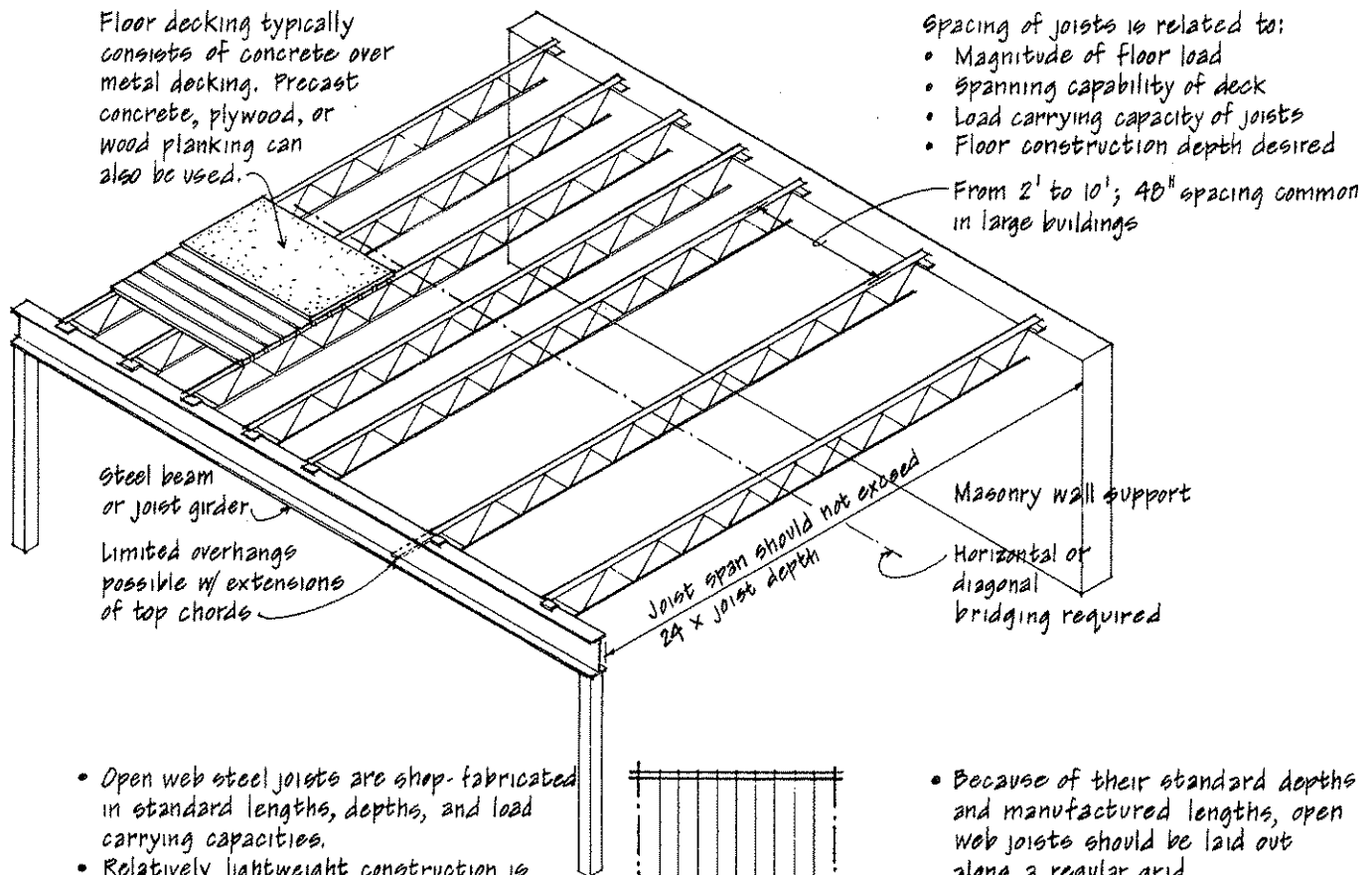


Floor decking typically consists of concrete over metal decking. Precast concrete, plywood, or wood planking can also be used.

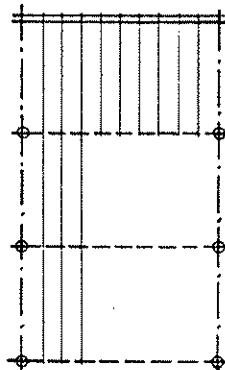
Spacing of joists is related to:

- Magnitude of floor load
- Spanning capability of deck
- Load carrying capacity of joists
- Floor construction depth desired

From 2' to 10'; 40" spacing common in large buildings



- Open web steel joists are shop-fabricated in standard lengths, depths, and load carrying capacities.
- Relatively lightweight construction is analogous to wood joist construction.
- Open webs permit the passage of mechanical services.
- Top chord bearing condition restricts the length of overhangs.
- Fire-resistance rating depends on the rating of the floor and ceiling assemblies. (See A.12.)

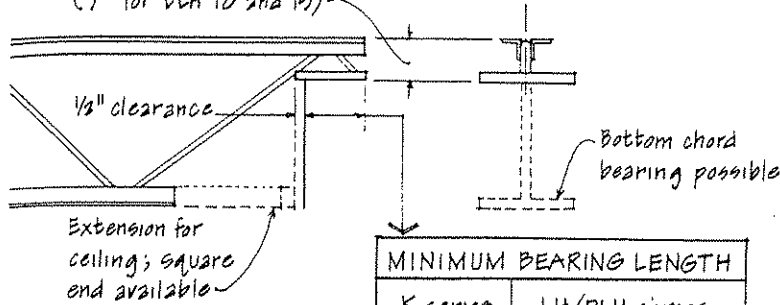


- Because of their standard depths and manufactured lengths, open web joists should be laid out along a regular grid.
- The system works most efficiently when carrying uniformly distributed loads.
- If properly engineered, concentrated loads may bear over panel points.

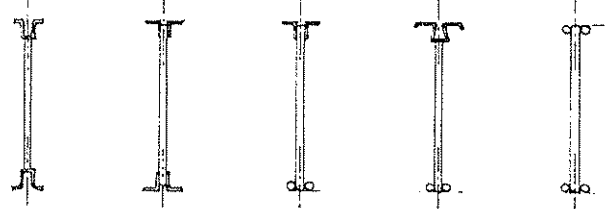
OPEN WEB STEEL JOISTS

4.25

2 1/2" for K series; 5" for LH/DLH series
(7" for DLH 18 and 19)



Profiles of open web steel joists vary according to manufacturer.



- Masonry wall support →
- Concrete wall support →
- Steel beam support →

MINIMUM BEARING LENGTH	
K series	LH/DLH series
4" to 6"	6" to 12"
4"	6" to 9"
2 1/2"	4"

OPEN WEB STEEL JOISTS		
Standard	K series	8" to 30" depths spanning up to 60'
Longspan	LH series	18" to 48" depths spanning up to 96'
Deep longspan	DLH series	52" to 72" depths spanning up to 144'

Horizontal or diagonal bridging is required to prevent lateral movement of joist chords. Spacing of bridging, from 10' to 20' o.c., depends on the joist span and chord size.

The following table is to be used for preliminary sizing of joists only. Consult the Steel Joist Institute for specifications and complete load tables for all joist types.

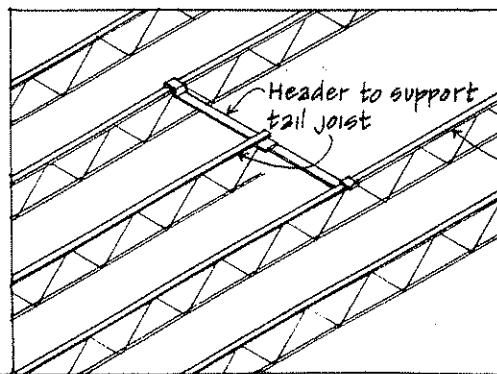
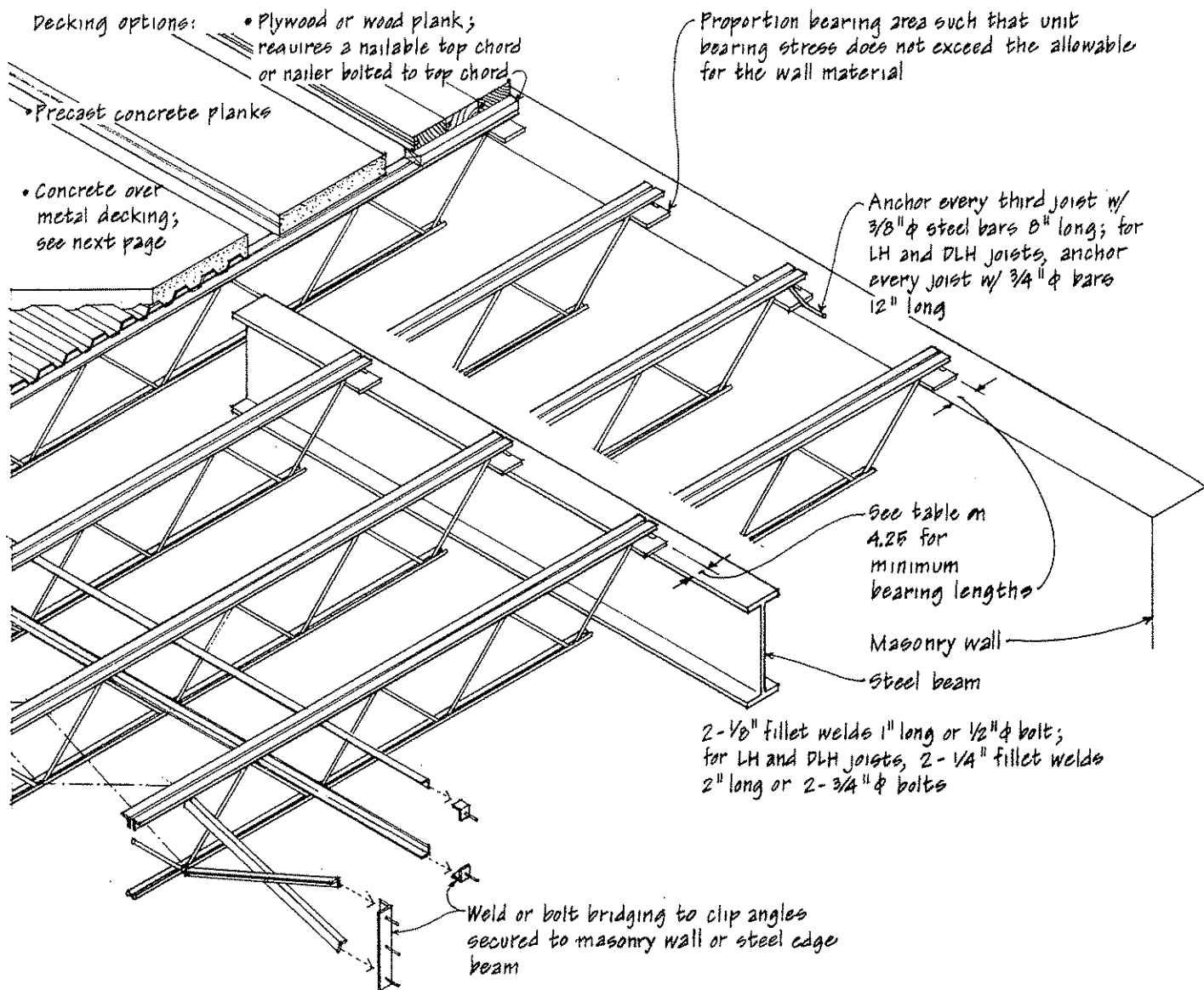
ALLOWABLE UNIFORMLY DISTRIBUTED LOAD (lbs. per S.F.)

Joist series	Joist designation	Span in feet										
		12	16	20	24	28	32	36	42	48	54	60
K	8 K 1	442	245									
	10 K 1	550	312	200								
	12 K 3	550	475	302	208							
	14 K 4		550	428	295	216						
	16 K 5		550	550	384	280	214					
	18 K 6			550	472	345	264	208				
	20 K 7			550	550	430	328	260				
	22 K 9				550	550	435	344	252			
	24 K 9				550	550	478	376	275	210		
	26 K 10					550	548	486	356	272		
	28 K 10					550	548	486	384	294	232	
	30 K 11						548	486	416	362	284	230
	30 K 12						548	486	416	364	324	262
LH	18 LH 5					580	448	354				
	20 LH 6					722	560	444				
	24 LH 7							588	446	342		
	28 LH 9								638	500	400	
	32 LH 10										450	389
	36 LH 11											450

Joist depth in inches

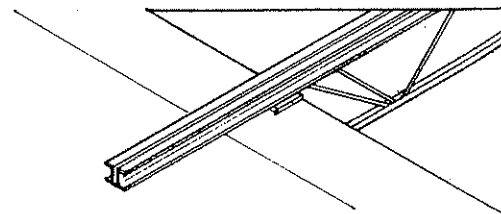
Chord
Joist type

4.26 OPEN WEB STEEL JOIST FRAMING

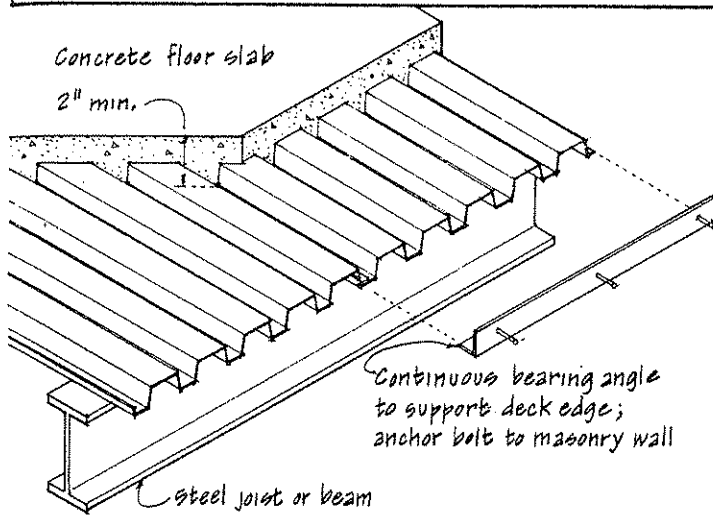


FLOOR OPENINGS:

Small openings may be framed with steel angle headers supported by trimmer joists. Large openings require structural steel framing.



Extended ends of steel angles or channel sections are available for short overhangs. For standard joists, the overhang may extend 5'-6", with an allowable load of 300 lbs. per linear foot.

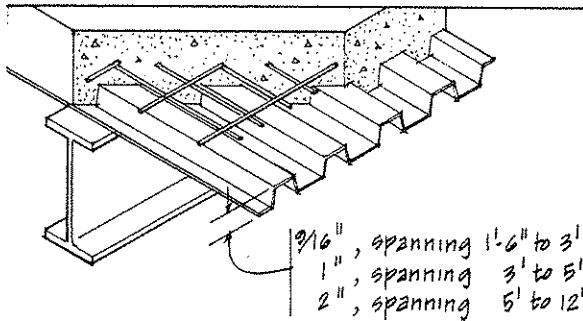


Metal decking is corrugated to increase its stiffness and spanning capability. The floor deck serves as a working platform during construction and as formwork for concrete.

- The decking panels are generally secured by puddle-welding through the decking to the supporting steel joists or beams.
- The panels are fastened to each other along their sides with screws or welds.
- If the deck is to serve as a lateral diaphragm, its perimeter must be welded to steel supports; in addition, more stringent requirements for support and side lap fastening may apply.

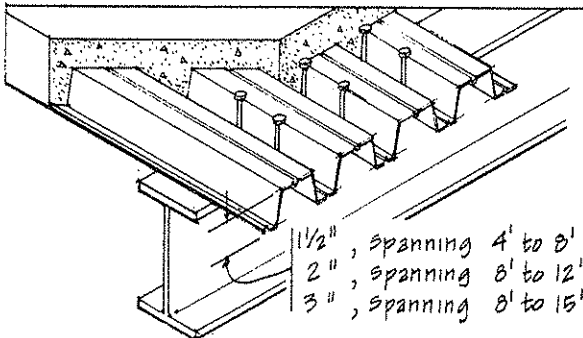
There are three types of metal decking:

FORM DECKING



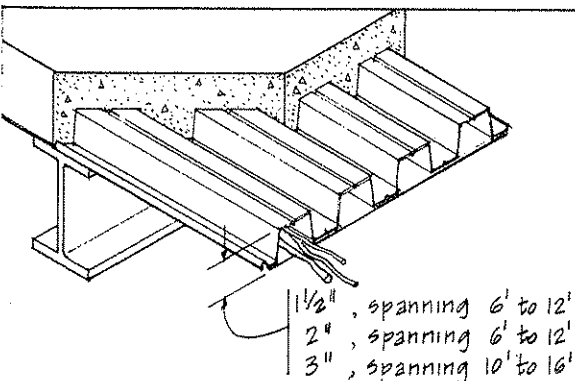
- The decking serves as permanent formwork for a reinforced concrete slab; it supports the concrete until the slab can support itself and its live load.

COMPOSITE DECKING



- The decking serves as tensile reinforcement for the concrete slab to which it is bonded with embossed rib patterns.
- Composite action between the concrete slab and the floor beams can be achieved by welding shear studs through the decking to the supporting below.

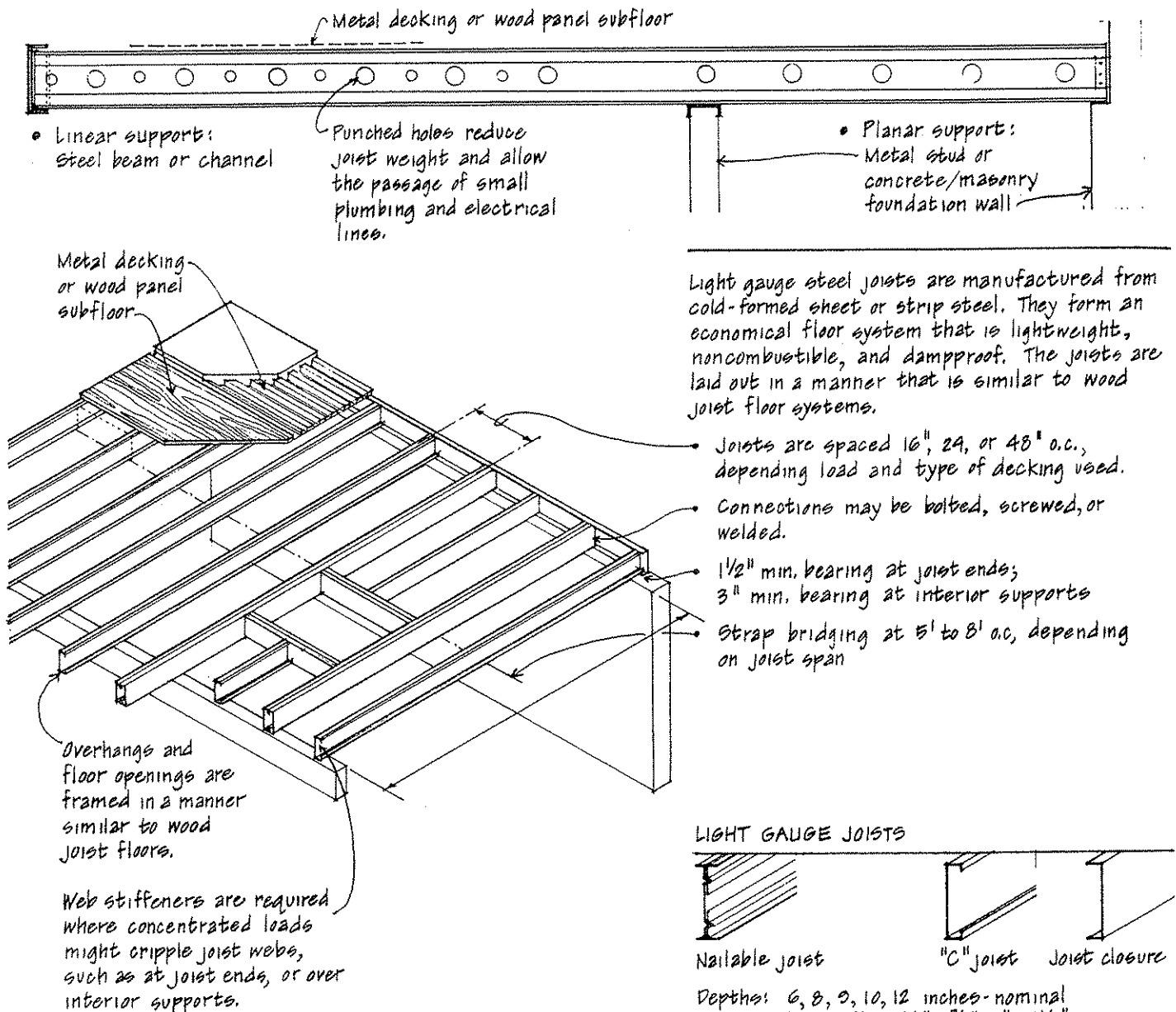
CELLULAR DECKING



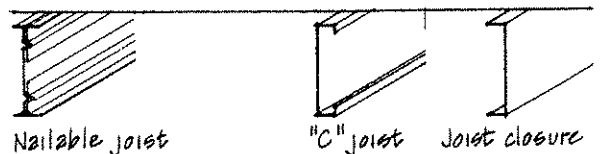
- Cellular decking is manufactured by welding a corrugated sheet to a flat one. The spaces created can be used as raceways for electrical and communications wiring; special cutouts are available for floor outlets.

Consult the manufacturer for patterns, widths, lengths, gages, finishes, and allowable spans.

4.28 LIGHT GAUGE STEEL JOIST FLOOR SYSTEM



LIGHT GAUGE JOISTS

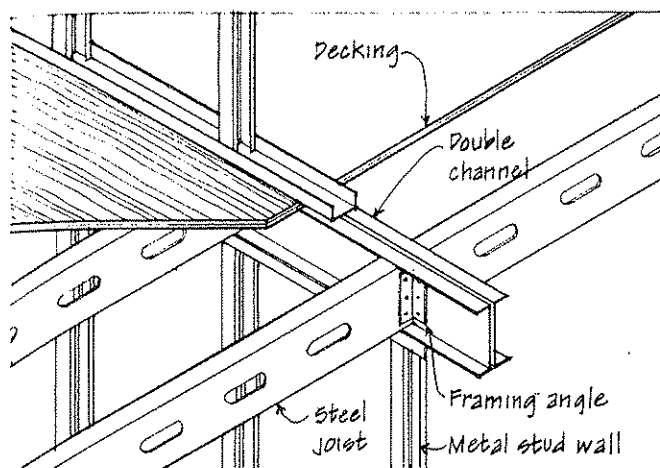


Depths: 6, 8, 9, 10, 12 inches-nominal
Flange widths: 1 5/8", 1 3/4", 1 7/8", 2", 2 1/2"
Gauges: 14 through 22

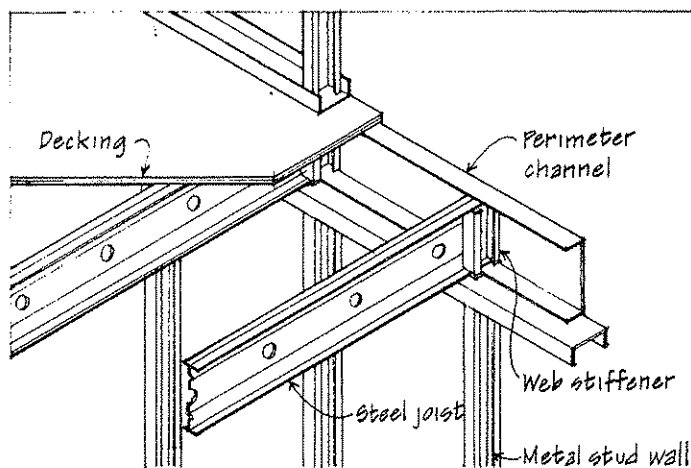
The following table is to be used for preliminary sizing only. Consult manufacturers' literature to confirm joist sizes, framing details, and allowable spans and loads.

ALLOWABLE UNIFORM LOADS (lbs. per S.F.)													
JOIST SIZE	SPACING	SPAN in feet					JOIST SIZE	SPACING	SPAN in feet				
		10	12	14	16	18			14	16	18	20	22
8"	16"	233	135	85	57	53	10"	16"	186	125	87	64	48
	24"	156	90	57	38	34		24"	124	83	58	43	32
	48"	78	45	28	19	17		48"	62	42	29	21	16
9"	16"			114	76	54	12"	16"				163	125
	24"			76	51	36		24"				109	82
	48"			38	26	18		48"				54	41

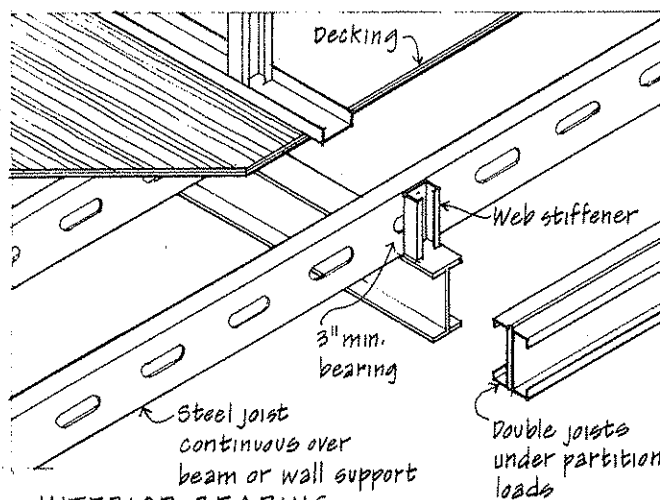
LIGHT GAUGE STEEL JOISTS: BEARING CONDITIONS



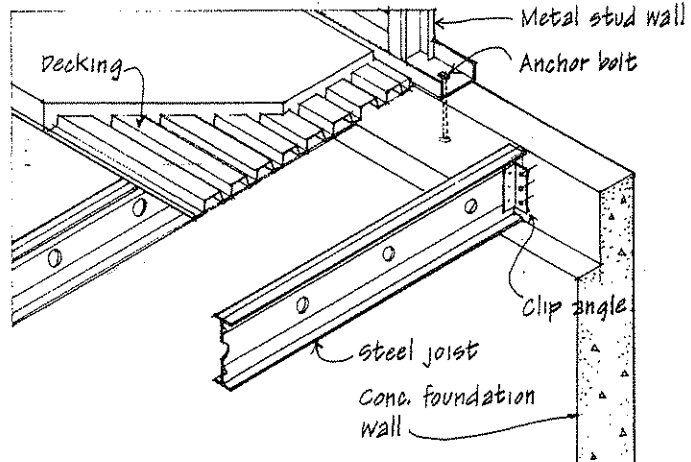
INTERIOR BEARING



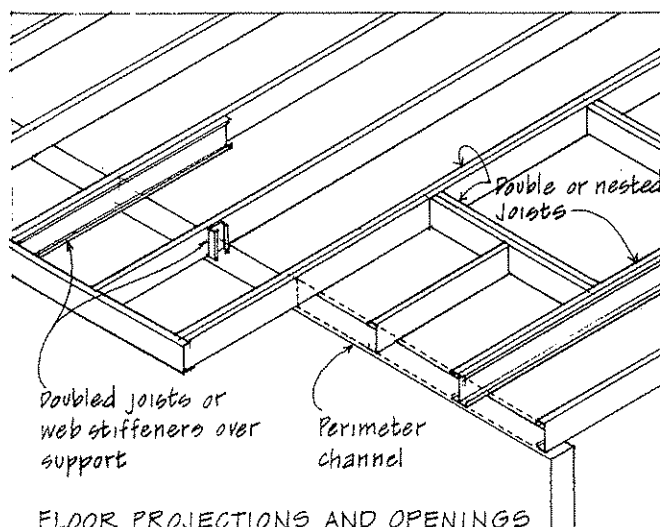
EXTERIOR BEARING



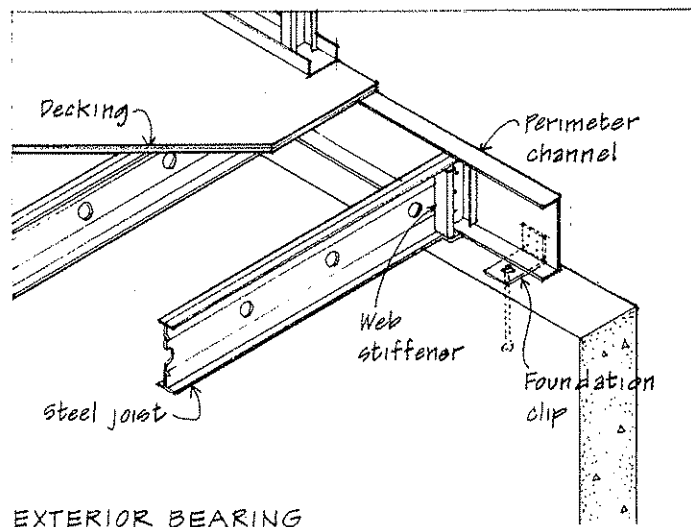
INTERIOR BEARING



EXTERIOR BEARING

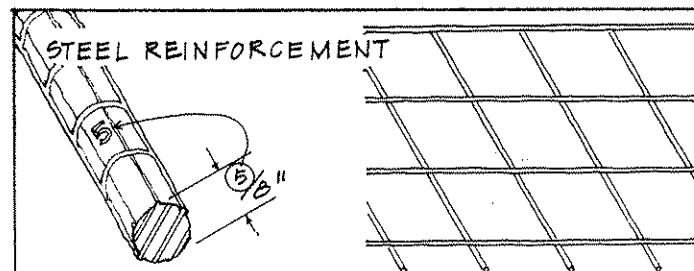
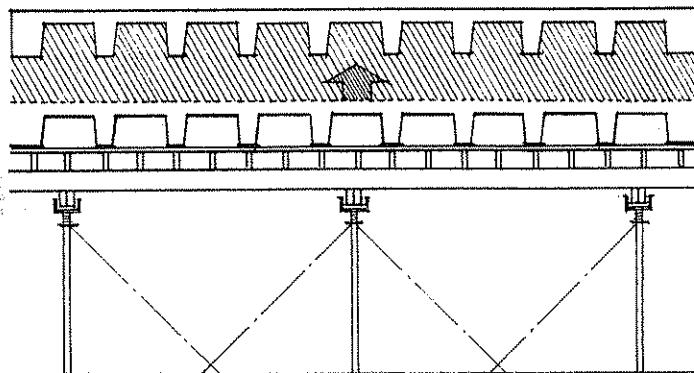
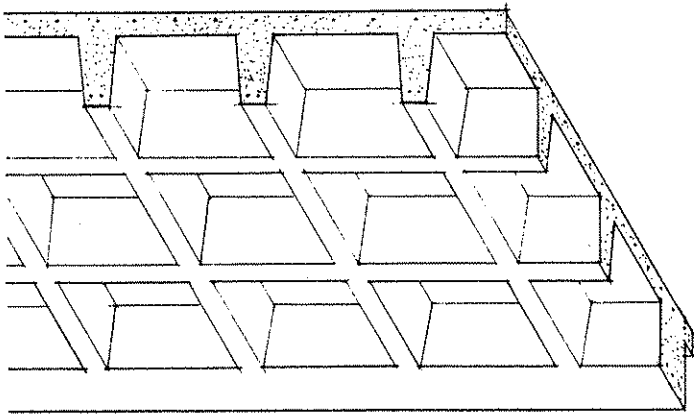


FLOOR PROJECTIONS AND OPENINGS



EXTERIOR BEARING

4.30 REINFORCED CONCRETE



REINFORCING BARS are hot-rolled steel sections that have ribs for better bonding to the concrete. The bar number refers to its diameter in eighths of an inch. eg., A #5 bar is $5/8$ " in diameter.

For cross-sectional area tables, see 12.9

WELDED WIRE FABRIC consists of cold-drawn wires arranged in a grid and welded at their points of intersection. The fabric is typically used to provide temperature reinforcement for slabs but the heavier gauges can also be used to reinforce concrete walls. The fabric is designated by the wire spacing and its gauge or cross-sectional area.

Reinforced concrete can be cast into almost any shape. Its flexibility of form is limited only by the formwork and steel reinforcement required, and the method used for its placement or casting. It may be formed into either linear or planar elements and configured into skeletal frame, bearing wall, or shell structures.

Concrete must be shaped and supported by formwork until it cures and can support itself. This formwork is often designed as a separate structural system because of the considerable weight and fluid pressure the concrete can exert on it.

The contact surfaces of forms are coated with a parting compound (oil, wax, or plastic) to aid in their removal. From a design standpoint, the shape of a concrete section must allow for the easy removal of the formwork. Use tapered sections where the formwork might otherwise be trapped by the surrounding concrete. Sharp external corners are usually bevelled or rounded to avoid chipping and ragged edges.

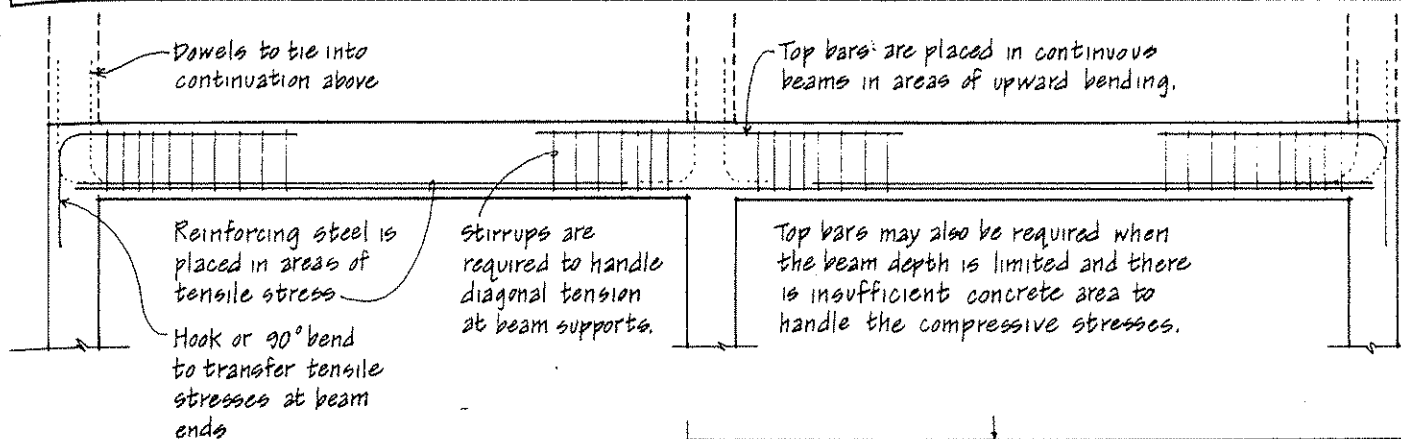
For economy, standard forms should be used in a repetitive manner. When possible, use columns and beams of a constant size and vary the amount of steel required.

Since concrete is relatively weak in tension, steel reinforcement is required to handle tensile stresses in structural concrete members. Steel reinforcement is also required to tie vertical and horizontal elements, reinforce the edges around openings, minimize shrinkage cracking, and control thermal expansion and contraction.

Reinforcing steel must be protected by the surrounding concrete against fire and corrosion. Minimum requirements for cover and spacing are specified by the American Concrete Institute (ACI) Building Code Requirements for Reinforced Concrete according to the concrete's exposure, and the size of the coarse aggregate and steel used. These requirements are noted on the following drawings where appropriate. See also 12.9.

Reinforcement should be designed by a qualified structural engineer.

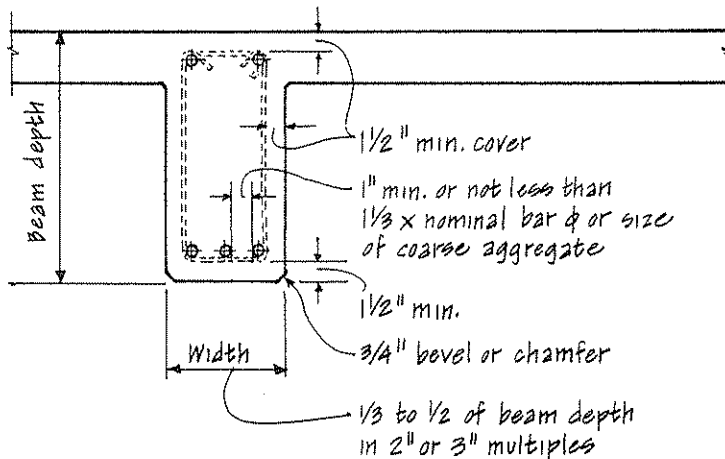
REINFORCED CONCRETE BEAMS



Sitecast concrete beams are almost always formed and cast along with the slab they support. Since a portion of the slab acts as a part of the beam, the depth of the beam is measured to the top of the slab. A rule of thumb for estimating a beam's depth is:

* Beam span in feet = Beam depth in inches.

Continuity between columns, beams, slabs, and walls is desirable to minimize bending moments at these junctures. Since continuity is easily attainable in concrete construction, structures continuous over 3 or more spans are usually the most efficient.

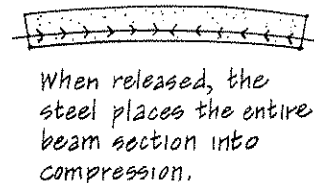
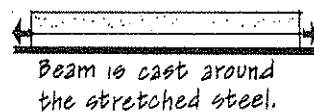
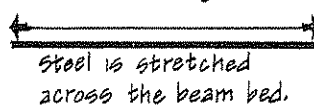


When loaded to its full load-carrying capacity, a conventionally reinforced concrete beam is susceptible to cracking under tension in its lower zone. Prestressing the beam reduces tension cracks by placing its entire cross-section into compression. This is achieved by stretching the reinforcing steel to a high tension, anchoring it at the beam ends, and then releasing it. Prestressing reduces beam deflection and allows the use of shallower beams and longer spans.

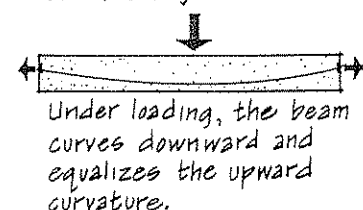
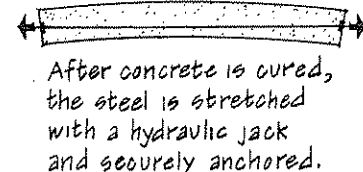
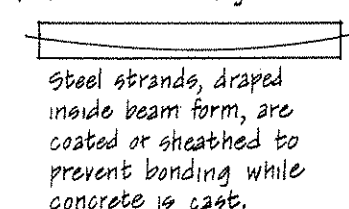
There are two types of prestressing techniques. Pretensioning is accomplished in a precasting plant. Post-tensioning is usually performed at the building site, especially when the structural units are too large to transport from factory to site.

PRESTRESSED CONCRETE BEAMS

◀ Pretensioning

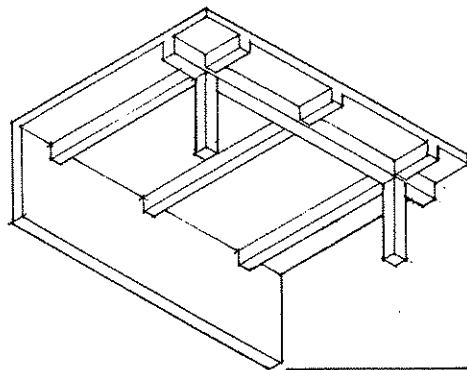


▷ Post-tensioning



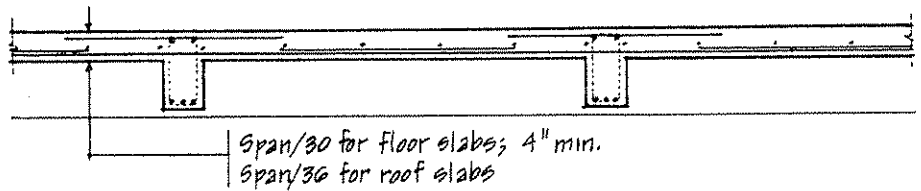
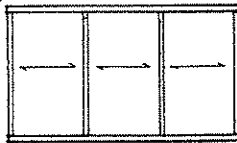
4.32

REINFORCED CONCRETE FLOOR SYSTEMS



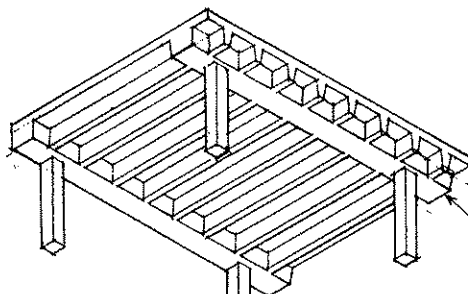
ONE-WAY SLAB

6' to 12' spans



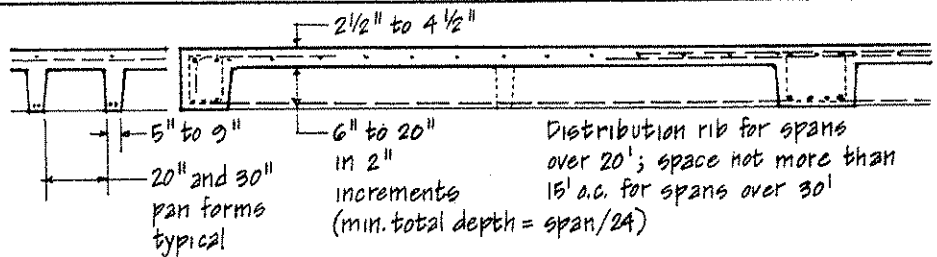
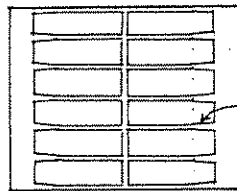
- Slab is supported on two sides by beams or bearing walls; beams, in turn, may be supported by girders or columns.

- One-way slabs are used for light to moderate loads over relatively short spans.
- Large module size is not as flexible for defining irregular bays as smaller modules of waffle slab.



ONE-WAY JOIST SLAB

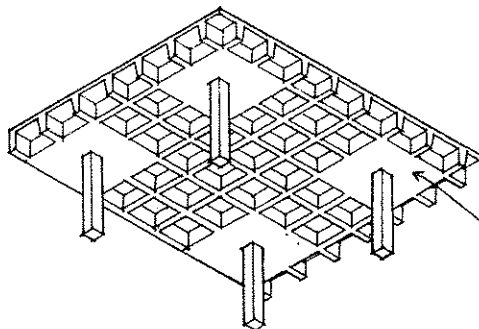
15' to 36' spans



- Joist band is an economical alternative to conventional beams; it has the same depth as the joists but is broader.

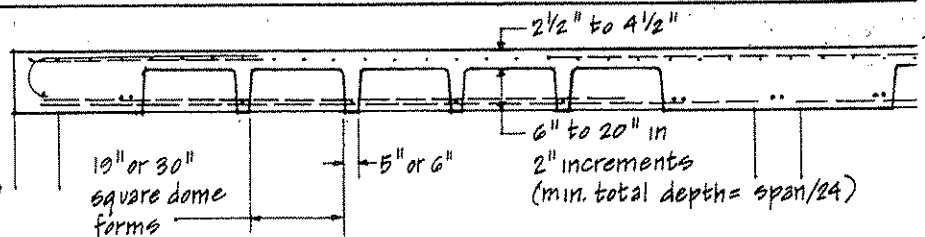
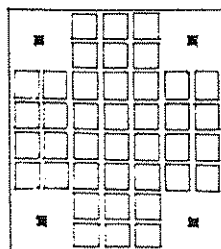
- One-way joist slabs are used for longer spans and heavier loads than practical for one-way solid slabs; not as suitable for large concentrated loads.

- Joists may be flared at the beam supports for greater shear resistance.



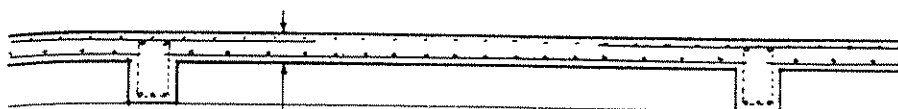
TWO-WAY WAFFLE SLAB

20' to 48' spans



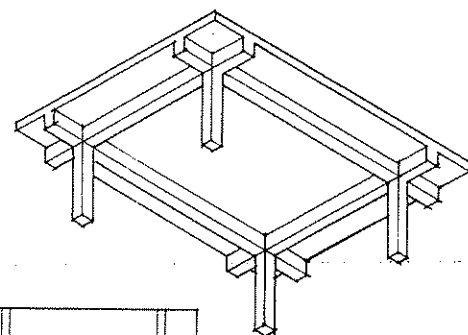
- Solid heads at column supports are formed by omitting dome forms; size depends on span and load conditions.

- Two-way waffle slabs are used for long spans and heavy loads.
- For maximum efficiency, bays should be as nearly square as possible.
- Waffle slabs can be efficiently cantilevered in two directions, up to $1/3$ of the main span.
- Coffered underside is often left exposed.

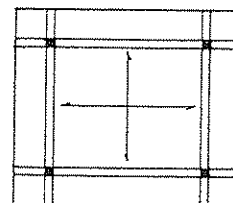


Depth = slab perimeter/180; 4" min.

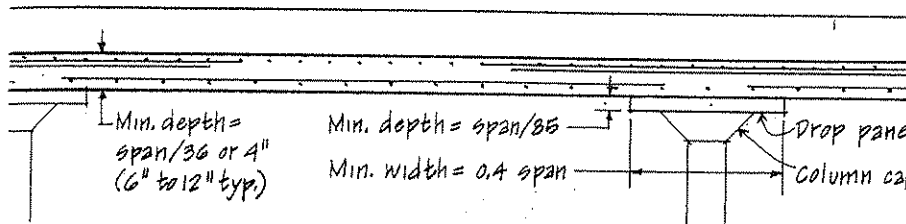
- Two-way slab is supported on four sides by beams; bay should be as nearly square as possible.
- Two-way slabs with beams are used for long spans and heavy loads, or when a high resistance to lateral forces is required. Two-way slabs, however, are usually made without beams. See below.



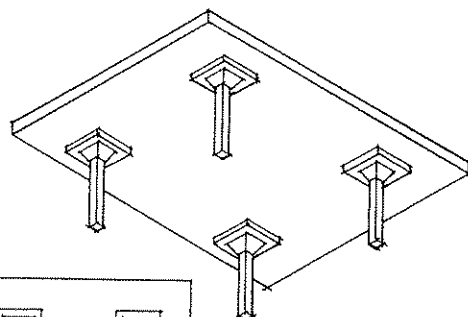
TWO-WAY SLAB WITH BEAMS



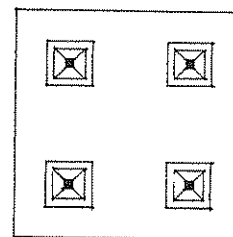
15' to 40' spans



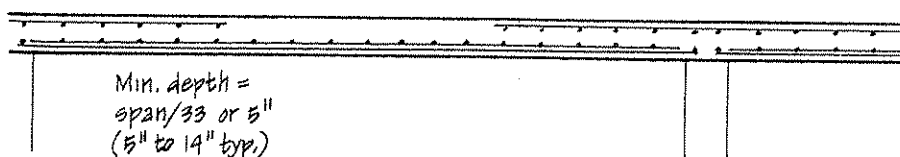
- Two-way slab is supported by columns without beams.
- Drop panels and/or column caps reinforce slab at column supports.
- Reinforcing steel is arranged to handle varying stresses within a slab of uniform thickness; this also applies to flat plates below.



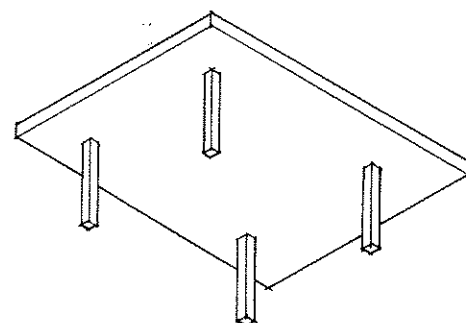
TWO-WAY FLAT SLAB



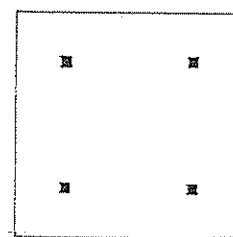
15' to 40' spans



- Minimal construction depth can minimize building height.
- Two-way flat plates are similar to two-way slabs but have no drop panels.
- Flat plates are suitable for moderate loads.
- They are simple to form, and permit some flexibility in column placement.



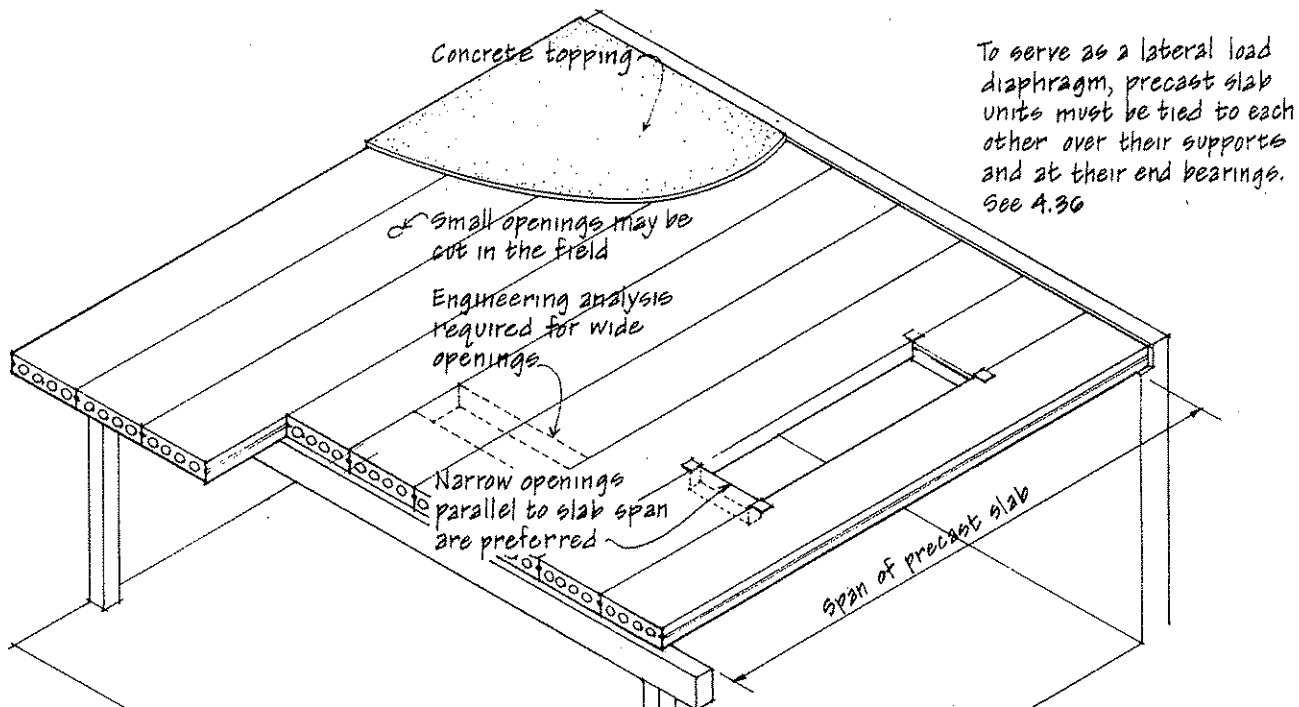
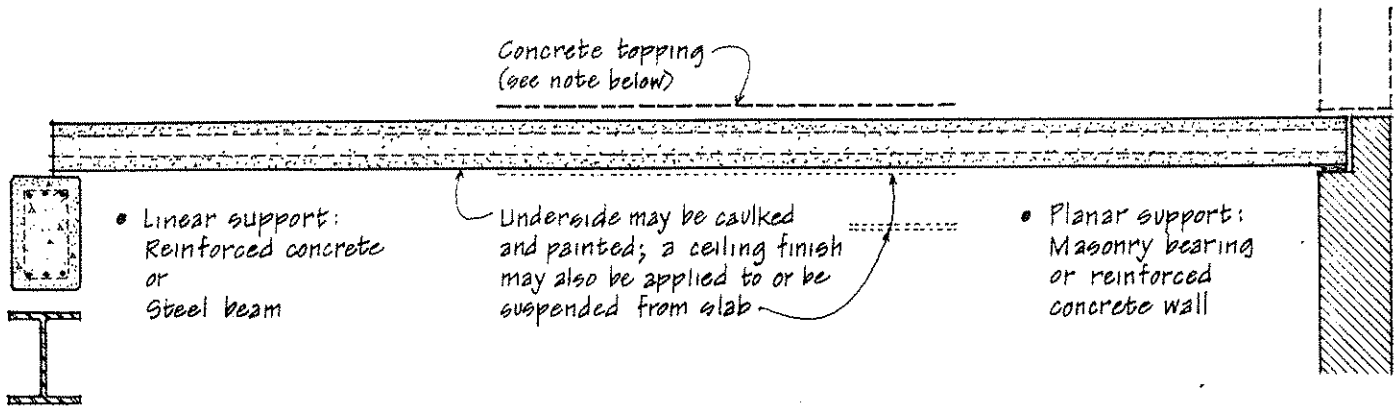
TWO-WAY FLAT PLATE



15' to 36' spans

4.34

PRECAST CONCRETE FLOOR SYSTEM

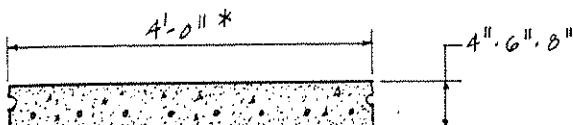
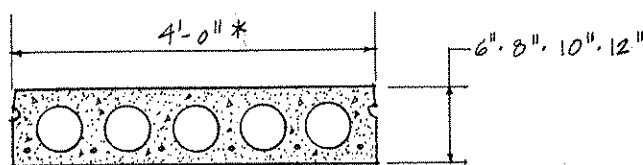
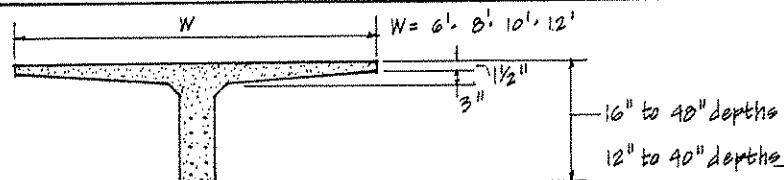
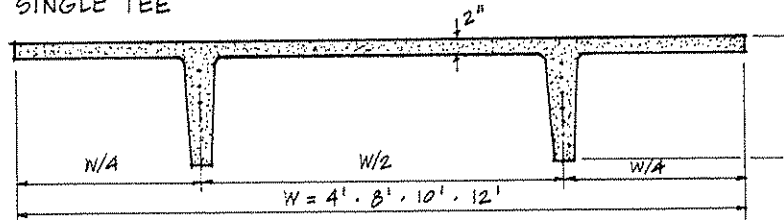

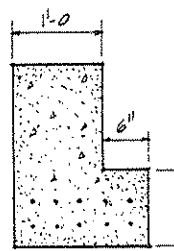
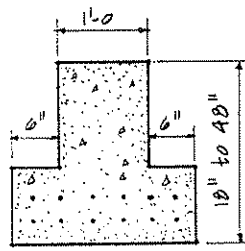


- Precast concrete slabs, beams, and structural tees are one-way spanning units; they are normally prestressed and may be of normal or lightweight concrete.
- The precast units are cast and cured in a plant off-site and transported to the building site for erection as rigid components; the size and proportion of the units may be limited by the means of transportation.
- Plant fabrication enables the units to have a consistent quality of strength, durability, and finish, and eliminates the need for on-site formwork.
- The modular nature of the standard-sized units may not be suitable for irregular building shapes.

- A 1½" to 2½" thick concrete topping bonds to the rough surface of the slab units, helps tie the units together, and conceals any surface irregularities.
- The topping can be reinforced with steel over supporting beams or walls for structural continuity and greater resistance to lateral loads.
- The topping can also increase the slab's fire-resistance rating as well as accommodate underfloor conduit for wiring.
- When the flooring is to be carpet and pad, the topping can be omitted if smooth-surface units are used.

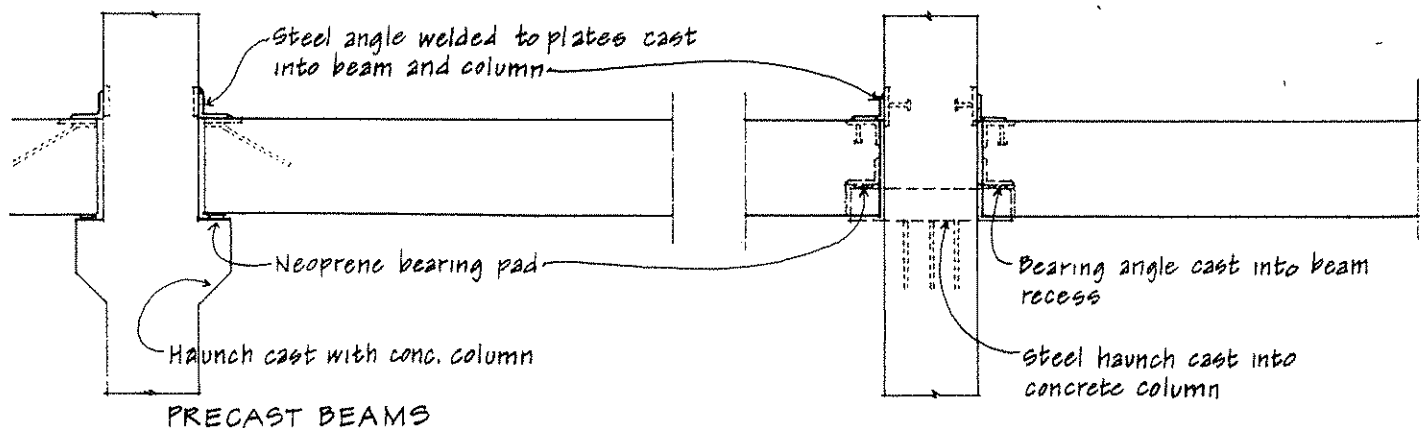
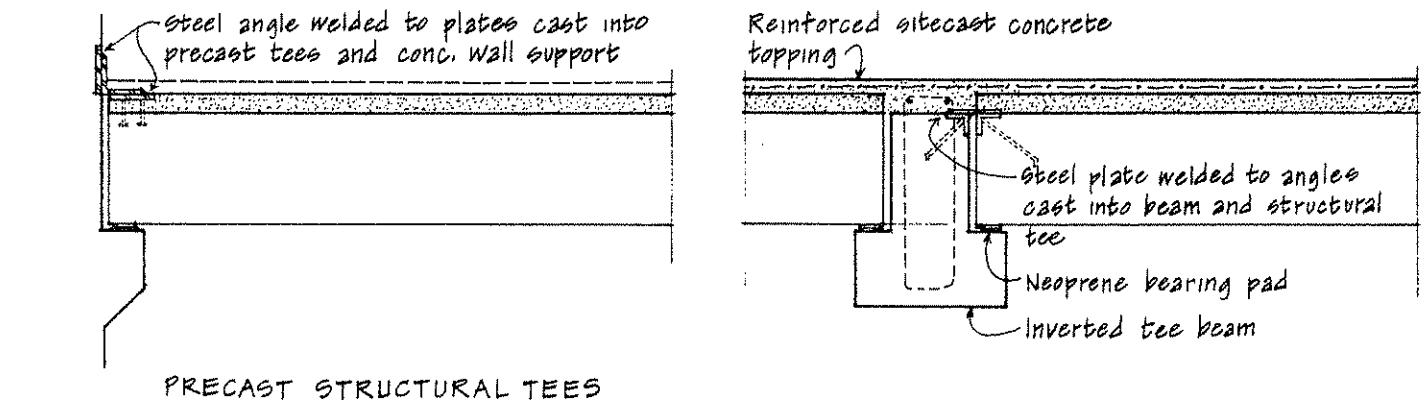
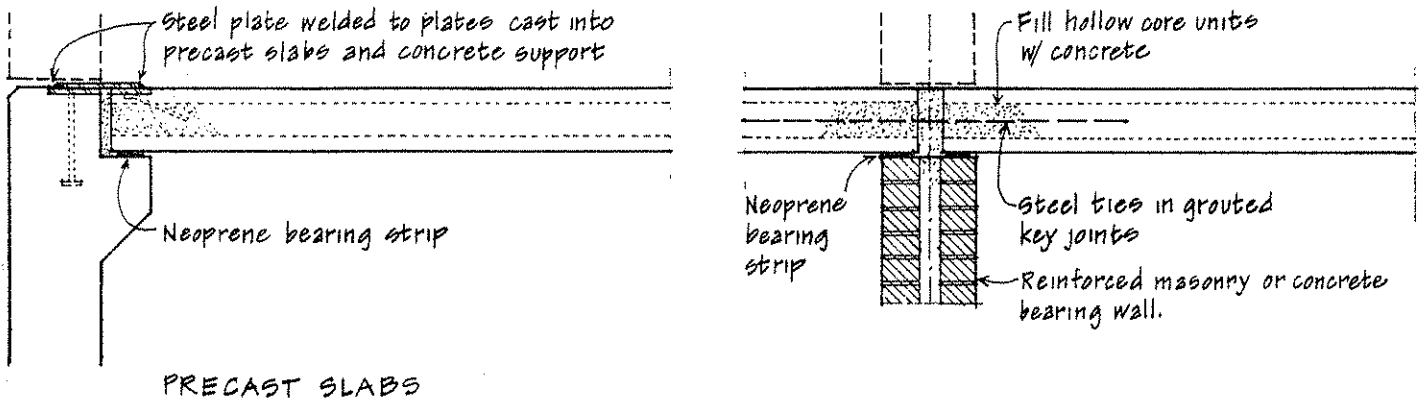
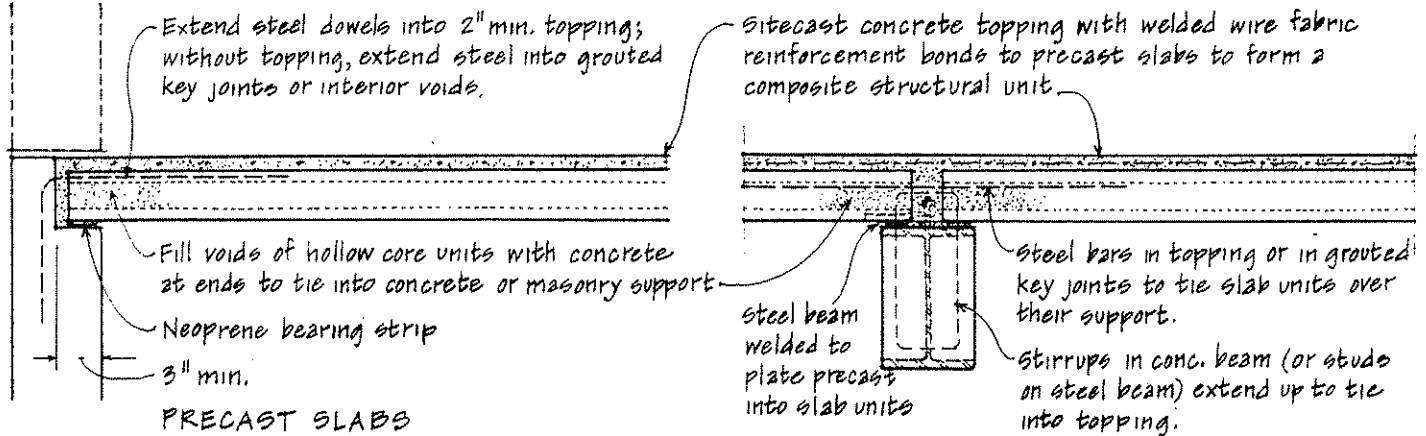
PRECAST CONCRETE STRUCTURAL UNITS

The table below illustrates the basic types of precast concrete structural units. The span ranges indicated are to be used for preliminary sizing only. Consult manufacturer for availability of sizes, exact dimensions, connection details, and span-load tables.

TYPE OF PRECAST CONCRETE UNIT	THICKNESS or DEPTH in inches	SPAN RANGE in feet												
<div></div> <p>* Exact dimension varies to allow space for reinforcement and grouting.</p> <p>SOLID FLAT SLAB</p>	<table><tr><td>4</td><td>12 - 16</td></tr><tr><td>6</td><td>14 - 24</td></tr><tr><td>8</td><td>18 - 30</td></tr></table>	4	12 - 16	6	14 - 24	8	18 - 30							
4	12 - 16													
6	14 - 24													
8	18 - 30													
<div></div> <p>* Also available in 1'-4", 2'-0", 3'-4", and 8'-0" widths.</p> <p>HOLLOW CORE SLAB</p>	<table><tr><td>6</td><td>14 - 22</td></tr><tr><td>8</td><td>20 - 32</td></tr><tr><td>10</td><td>24 - 40</td></tr><tr><td>12</td><td>30 - 44</td></tr></table>	6	14 - 22	8	20 - 32	10	24 - 40	12	30 - 44					
6	14 - 22													
8	20 - 32													
10	24 - 40													
12	30 - 44													
<div></div> <p>SINGLE TEE</p>	<table><tr><td>12</td><td>28 - 40</td></tr><tr><td>18</td><td>36 - 50</td></tr><tr><td>24</td><td>45 - 70</td></tr><tr><td>32</td><td>54 - 80</td></tr><tr><td>36</td><td>62 - 90</td></tr><tr><td>48</td><td>80 - 110</td></tr></table>	12	28 - 40	18	36 - 50	24	45 - 70	32	54 - 80	36	62 - 90	48	80 - 110	
12	28 - 40													
18	36 - 50													
24	45 - 70													
32	54 - 80													
36	62 - 90													
48	80 - 110													
<div></div> <p>DOUBLE TEE</p>														
<div></div> <p>Rectangular BEAMS</p>														
<div></div> <p>L-shaped</p>														
<div></div> <p>Inverted tee</p>	<table><tr><td>20</td><td>18 - 30</td></tr><tr><td>28</td><td>22 - 40</td></tr><tr><td>36</td><td>26 - 50</td></tr><tr><td>44</td><td>30 - 56</td></tr><tr><td>52</td><td>34 - 70</td></tr><tr><td>60</td><td>42 - 80</td></tr></table>	20	18 - 30	28	22 - 40	36	26 - 50	44	30 - 56	52	34 - 70	60	42 - 80	
20	18 - 30													
28	22 - 40													
36	26 - 50													
44	30 - 56													
52	34 - 70													
60	42 - 80													

4.36

PRECAST CONCRETE STRUCTURAL UNITS: SUPPORT CONDITIONS



WALL SYSTEMS

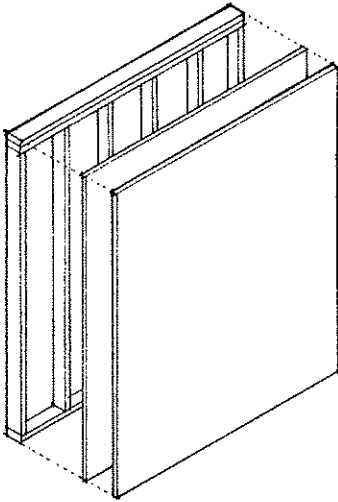
Wall systems are the vertical planes of a building which define and enclose its interior spaces. They may be bearing walls of homogeneous or composite construction, or they may be constructed of linear columns and beams with nonstructural panels filling in between them. How these walls and columns support floor and roof systems above, and how they are supported in turn by wall and foundation systems below, are determined by the structural compatibility of these systems and the type of materials and connections used. If rigid, walls can also serve as shear planes which are designed to resist lateral wind and earthquake forces.

Exterior walls serve as a protective shield against the weather for a building's interior spaces. Their construction should control the passage of heat and cold, air, moisture, and water vapor. The exterior skin, which may either be applied to or be integral with the wall structure, should be durable and resistant to the weathering effects of sun, wind, and rain.

The interior walls which subdivide the space within a building may be either nonstructural or load-bearing. Their construction should be able to support the desired finish materials, provide the required degree of acoustical separation, and accommodate when necessary runs of mechanical and electrical lines.

The size and location of door and window openings in walls are determined by the requirements for natural light, ventilation, view, and physical access. These openings must be constructed so that any vertical loads are distributed around the openings and not transferred to the door and window units themselves.

2. COMPARATIVE WALL SYSTEMS

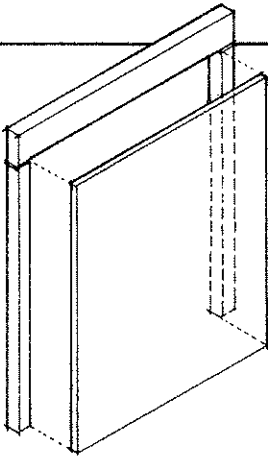


WOOD STUD WALLS

- Walls are normally 2x4s, but may be 2x6s or larger to accommodate more thermal insulation or rise more than 14 feet.
- Studs are spaced 16" or 24" o.c.; this spacing is related to the width and length of common sheathing materials.
- Studs carry vertical loads while the wall sheathing or diagonal bracing help to make the frame rigid.
- Thermal insulation, vapor barriers, and small mechanical services can be accommodated within the stud wall frame.
- Stud frames can accept a variety of interior or exterior wall finishes; some finishes require a nail-base sheathing.
- The fire-resistance rating of the wall assembly depends on its finish materials.
- Stud wall frames may be fabricated on-site or panelized off-site.
- Stud walls are flexible in form due to the workability of relatively small pieces and the various means of fastening available.

METAL STUD WALLS

- Metal stud walls are similar in structure to wood stud walls.
- Connections may be screwed or welded.

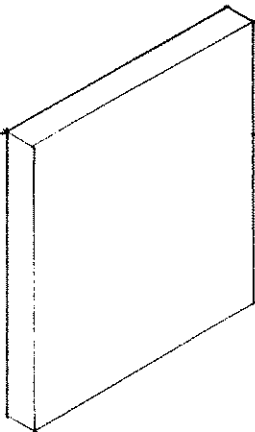


WOOD POST AND BEAM FRAMING

- Post and beam system uses fewer but larger structural members than stud framing.
- Frame requires diagonal bracing, shear planes, or rigid connections for lateral stability.
- Detailing of connections is critical for structural and visual reasons. Frame may be left exposed.
- Non-bearing infill panels enclose space and, on exterior walls, serve as a weather barrier.
- It may be difficult to accommodate mechanical and electrical services within the structural framework.
- Posts are usually laid out along a grid to support plank and beam floor and roof structures.

STEEL AND REINFORCED CONCRETE FRAMES

- Steel and concrete frames are similar in form to wood post and beam structures.
- Stronger materials can span greater distances and carry heavier loads; rigid connections are feasible.
- Structural frame can support a variety of curtain wall systems.



MASONRY AND CONCRETE BEARING WALLS

- Masonry and concrete bearing walls rely on their mass for their load carrying capability; while strong in compression, they may require reinforcing to handle any tensile stresses.
- Their height-to-width ratio, provisions for lateral stability, and proper placement of expansion joints are critical.
- Wall surface may be left exposed; materials have good fire-resistance.
- Mechanical and electrical services may be integrated into wall.
- Thermal insulation may be contained in wall cavity or be applied to wall surface.

FACTORS IN WALL DESIGN AND CONSTRUCTION

Strength in:

- Supporting vertical loads from floor, wall, and roof structures above
- Resisting lateral wind and seismic forces and lateral loads from supported floor and roof structures.

Connection to foundation, floor, and roof systems:

- Floor and roof systems may bear on the wall system so that their edges are exposed and cantilevers are made possible.
- Floor and roof systems may frame into the wall system which is continuous for the height of the building.

Wall finish desired:

- Compatibility between base material of wall and desired wall finish
- Visual characteristics of color, texture, pattern, and jointing.

Door and window openings:

- Structural and/or modular limitations on size, proportion, and location
- Effect on daylighting and potential for heat loss or gain.

Weathertightness and the control of:

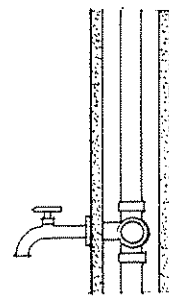
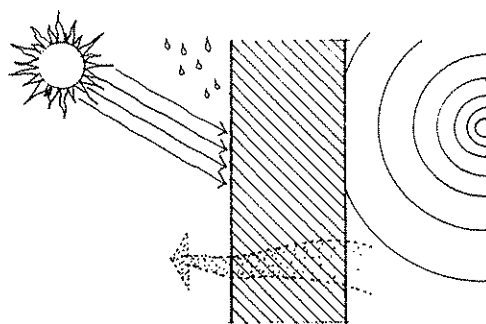
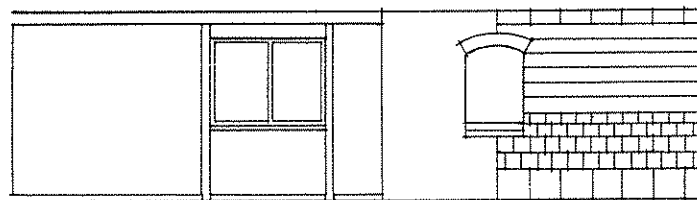
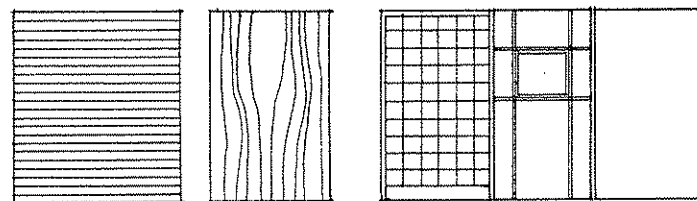
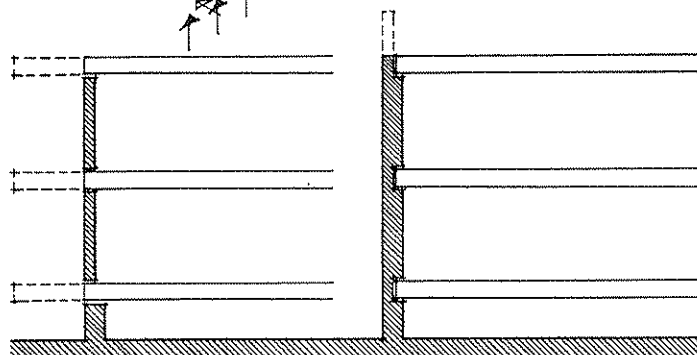
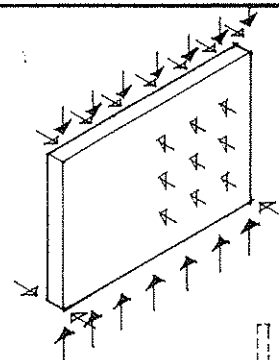
- Heat flow
- Air infiltration
- Moisture and water vapor flow
- Sound transmission.

Expansion and contraction:

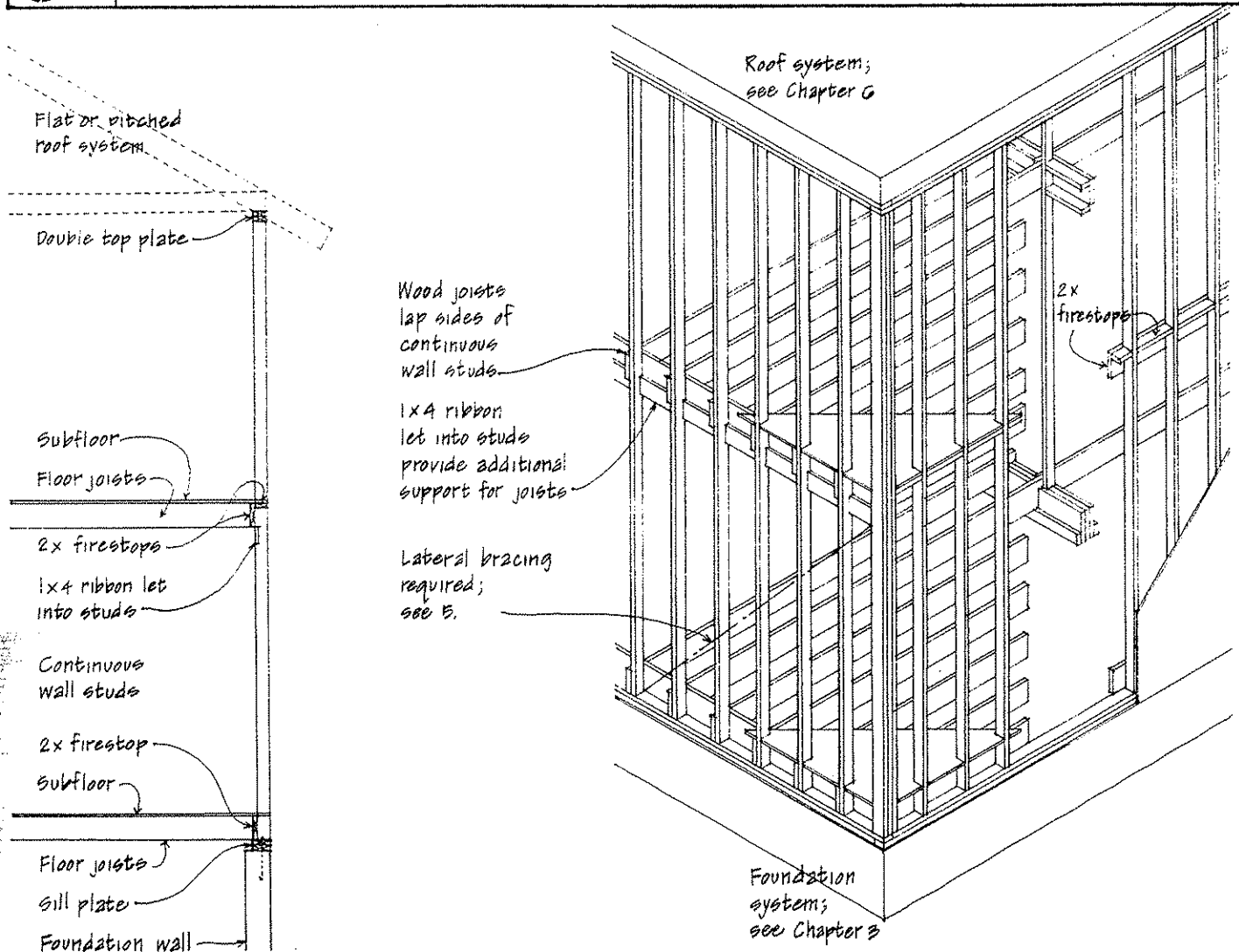
- Type and location of expansion joints, if required.

Accommodation of mechanical and electrical services and outlets.

Fire-resistance rating desired or required by the building code.



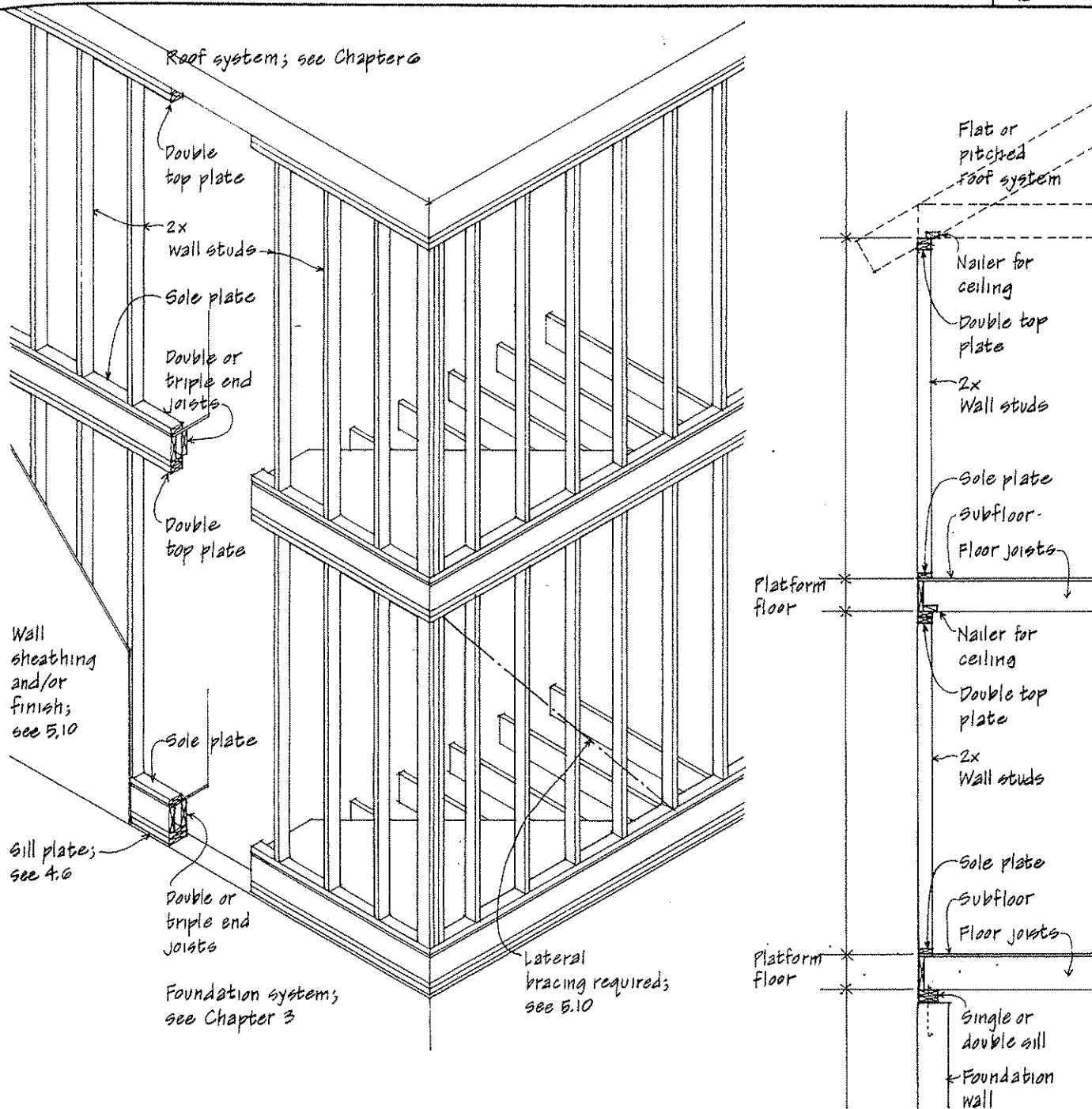
4 BALLOON FRAMING



- 2x4 or 2x6 studs spaced 16" or 24" o.c. are continuous for full building height.
- Balloon framing is rarely used today but minimal vertical movement may be desirable for brick veneer and stucco finishes.
- First floor joists bear on a foundation sill plate while second floor joists lap the studs and rest on a continuous ribbon let into the studs.
- Concealed spaces in frames require 2x firestops to prevent drafts between stories and between a top story and the roof.

WALL STUD SIZES for both balloon and platform framing	Max. unsupported height	Maximum spacing
2x4 studs	14'	16" o.c., except when supporting only a ceiling and roof, 2x4 studs not more than 10' high may be spaced 24" o.c.
2x6 studs	20'	24" o.c., except when supporting 2 stories and a roof, space 2x6 studs not more than 16" o.c.

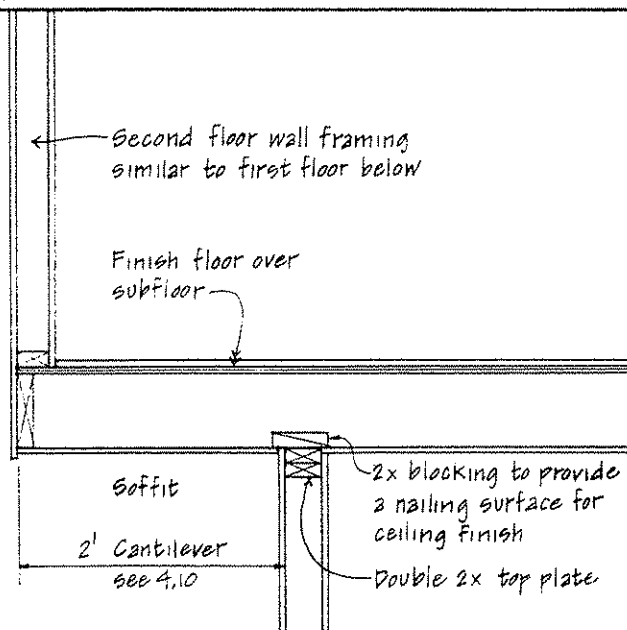
PLATFORM FRAMING



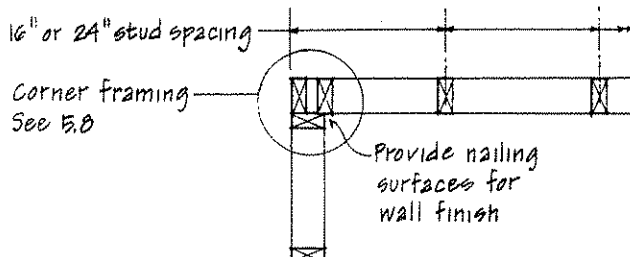
- 2x4 or 2x6 story height studs are spaced 16" or 24" o.c.
- Floor joists rest on foundation sill plate or top plate of stud wall below.
- Subfloor extends to outer edge of wall frame and serves as a work platform.
- Although vertical shrinkage is greater than in balloon framing, it is equalized between floors.
- Stud walls are adaptable to off-site fabrication as panels and tilt-up construction.
- Concealed spaces within frame require 2x firestops to prevent drafts between stories and between a top story and the roof.

D.6

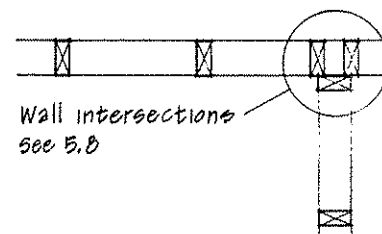
WOOD STUD WALL SECTIONS



See 4.9 for various floor/partition connections



PLAN OF STUD WALL FRAMING



Exterior wall sheathing and/or finish

Thermal insulation and vapor barrier see 8.25-8.27

6" min. clearance between untreated wood and grade

Slope away from structure

2x studs @ 16" or 24" o.c.; see 5.4 for size and spacing requirements; 2x3 studs @ 16" o.c. may be used for interior nonbearing partitions

Interior wall finish

2x sole plate

Finish floor over subfloor

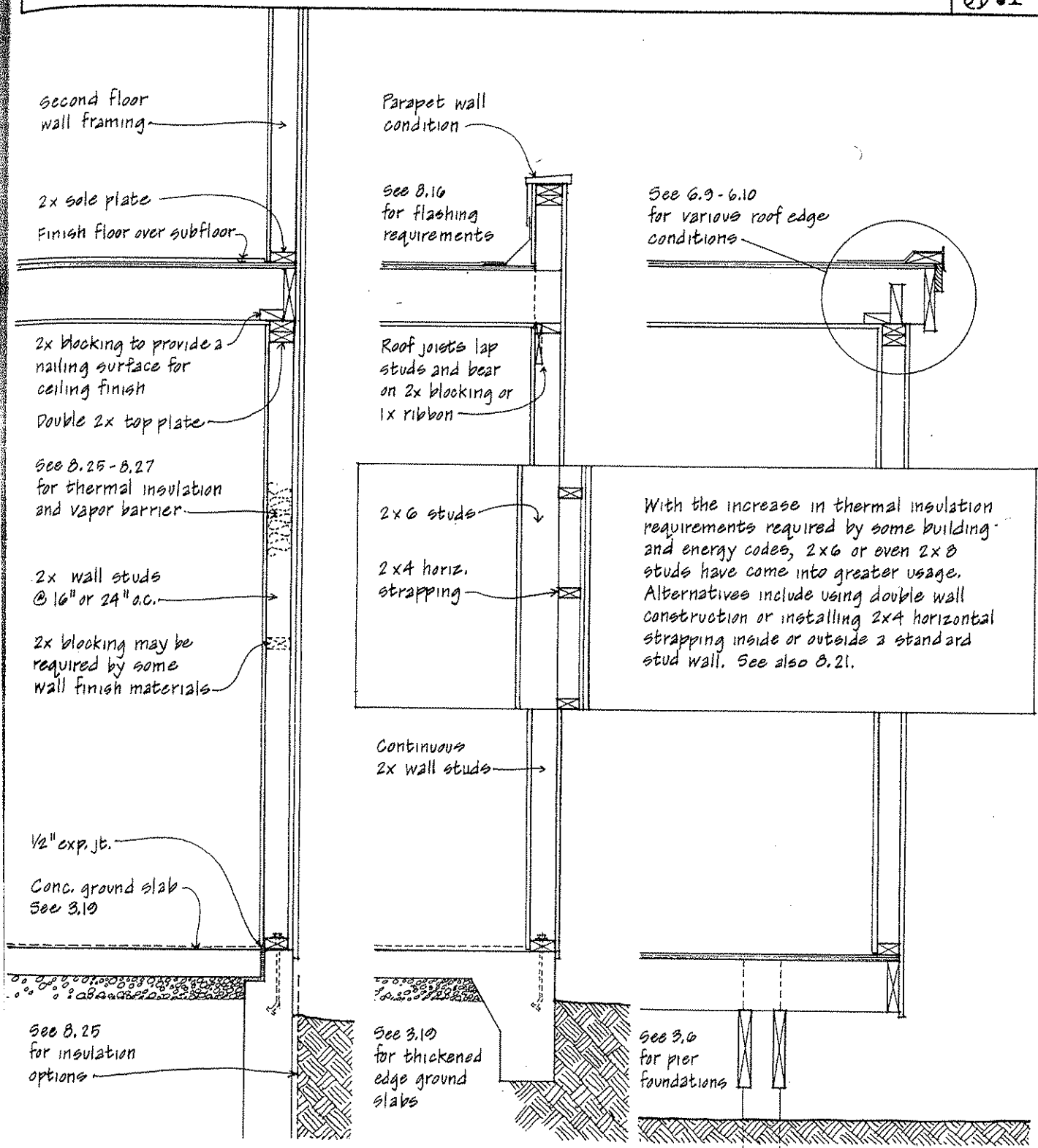
Wood joist floor system; see 4.4

2x sill anchored to foundation wall; see 4.6

Provide beam or wall support for interior load-bearing partitions; see 4.9

SECTION THROUGH EXTERIOR WALL

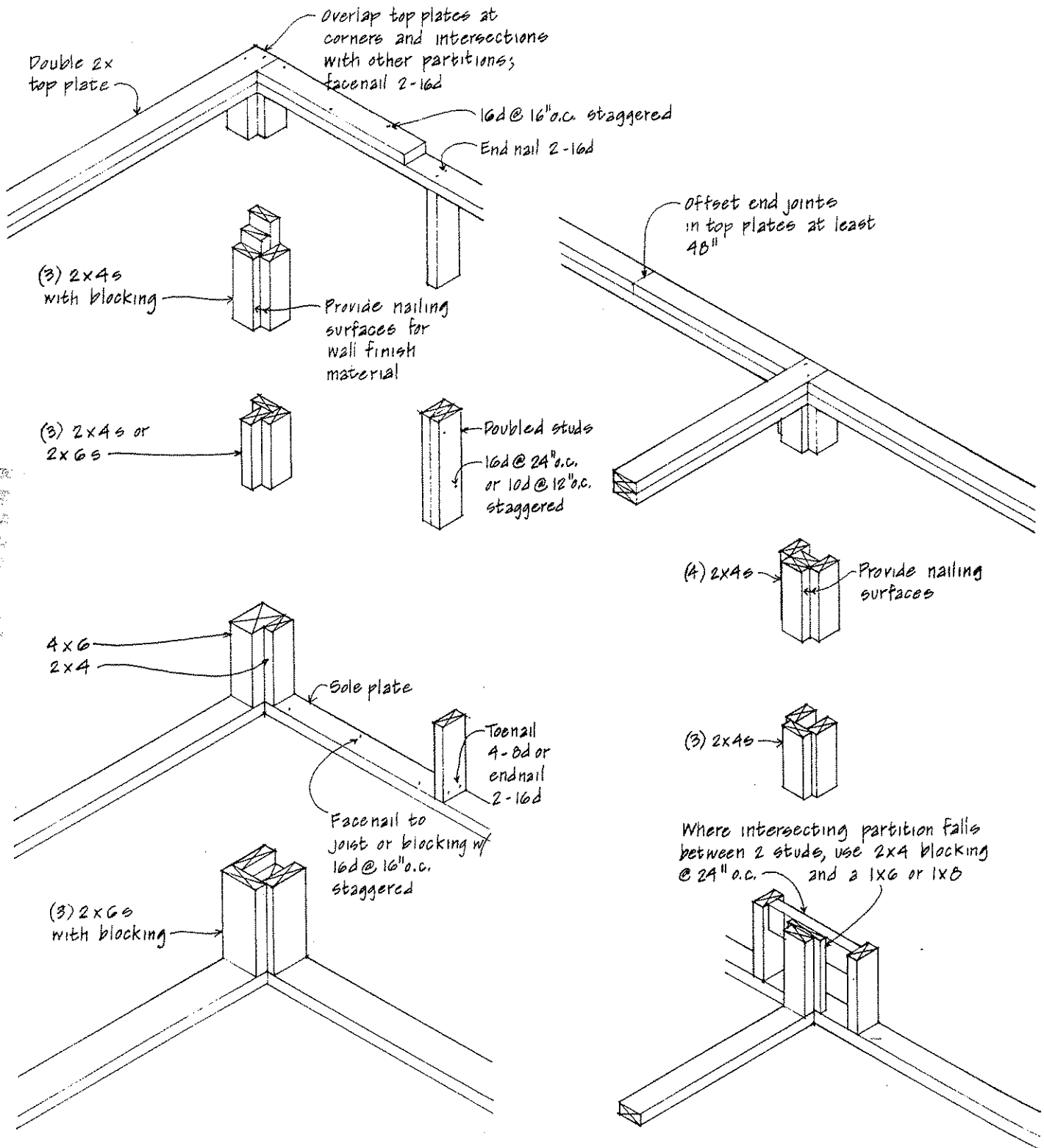
INTERIOR PARTITION



NOTE: The wall sections on this and the preceding page are not intended to be complete. They exclude specific wall, floor and ceiling finishes, trim, insulation, and vapor barriers. Instead, they attempt to illustrate the ways wood stud walls connect to various foundation, floor, and roof systems. Wood stud walls are typically used with wood joist and rafter systems.

No. 8

WOOD STUD WALLS: CORNERS AND PARTITION INTERSECTIONS

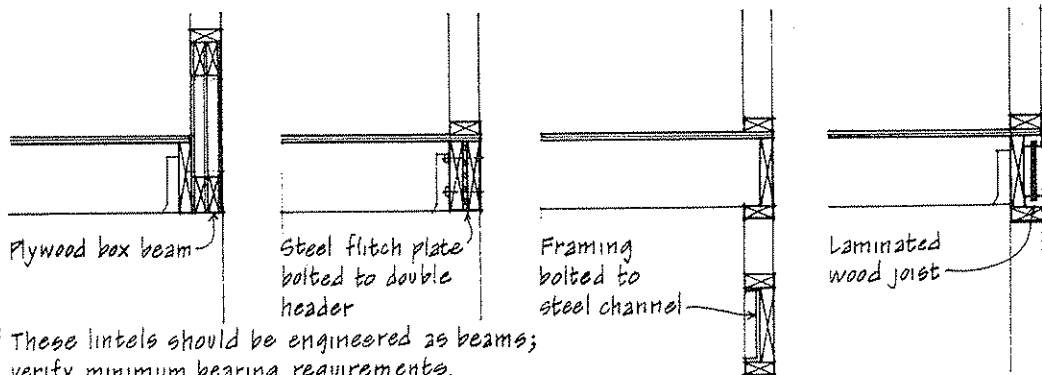
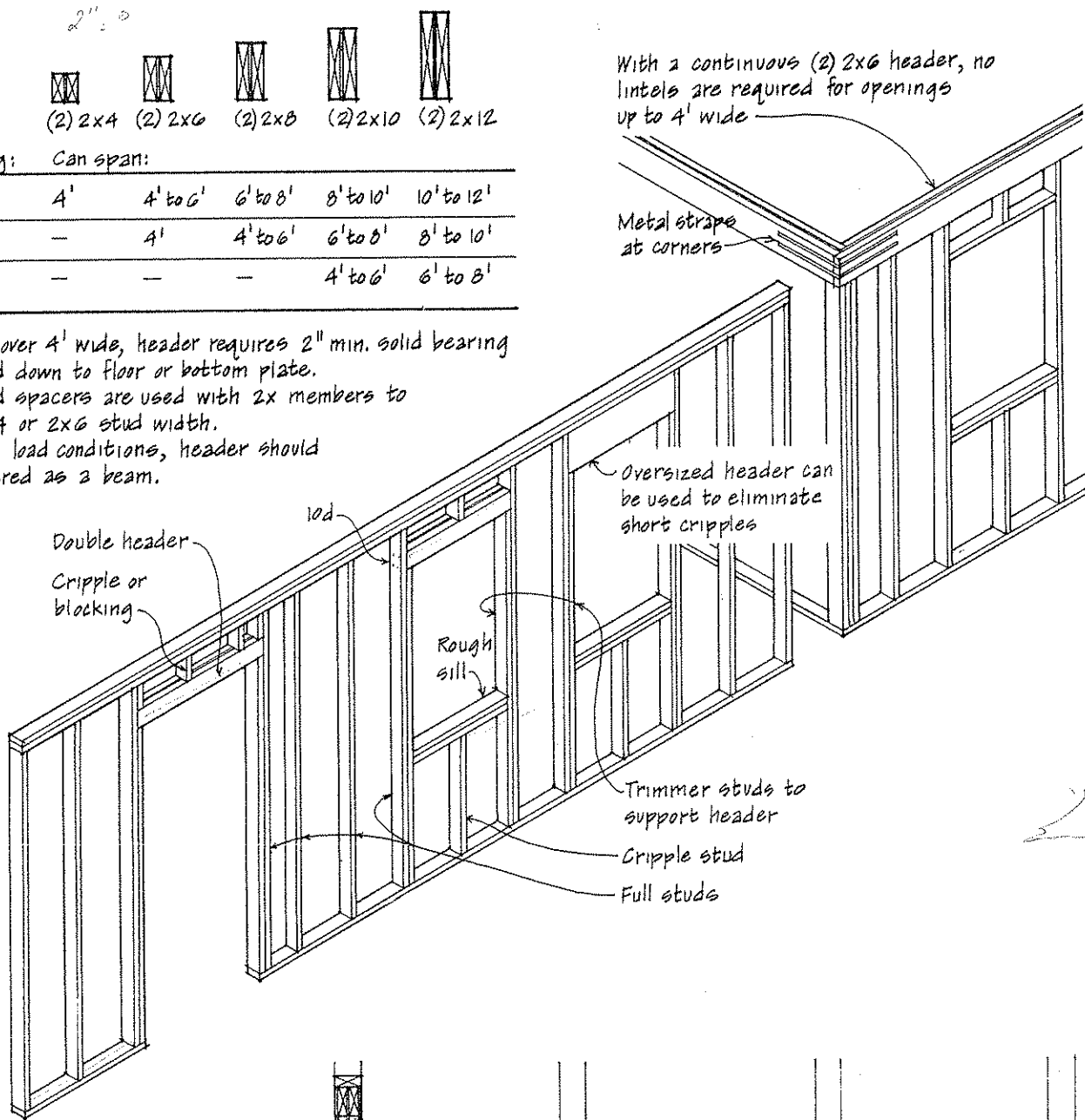
CORNER STUD FRAMING ASSEMBLIESINTERSECTING PARTITIONS

WOOD STUD WALLS: DOOR AND WINDOW OPENINGS

2" min.

HEADERS	(2) 2x4	(2) 2x6	(2) 2x8	(2) 2x10	(2) 2x12
Supporting:	Can span:				
Roof only	4'	4' to 6'	6' to 8'	8' to 10'	10' to 12'
1 story	—	4'	4' to 6'	6' to 8'	8' to 10'
2 stories	—	—	—	4' to 6'	6' to 8'

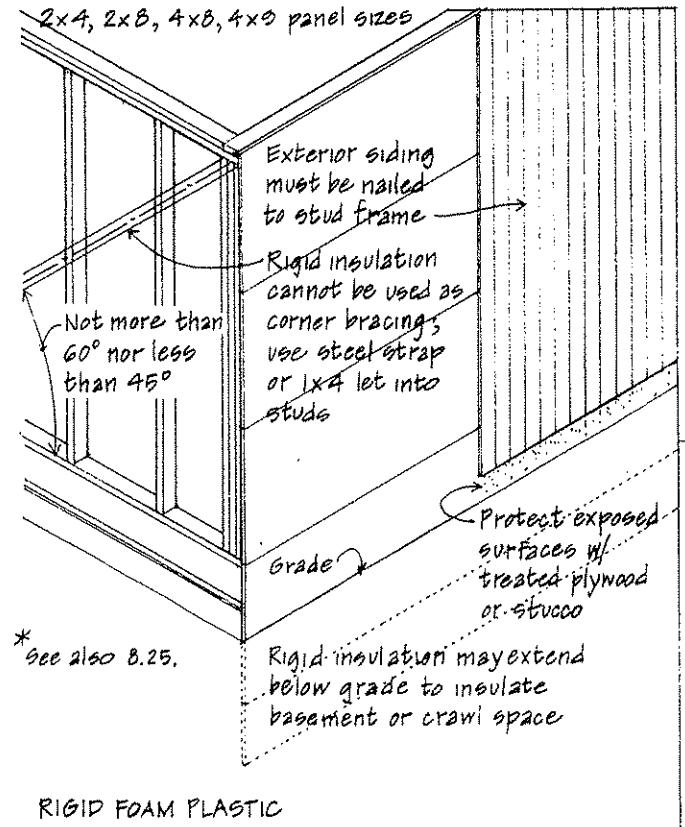
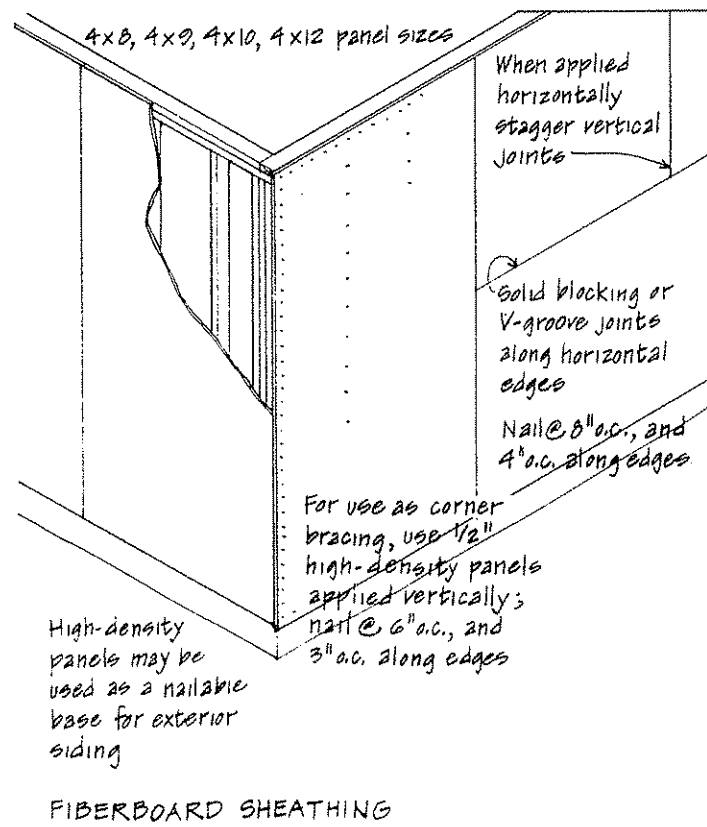
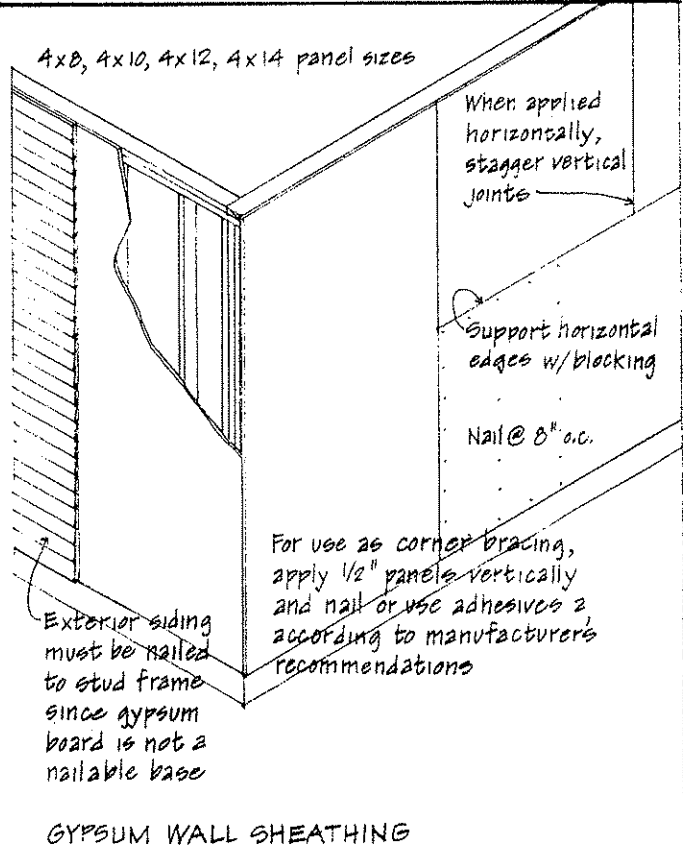
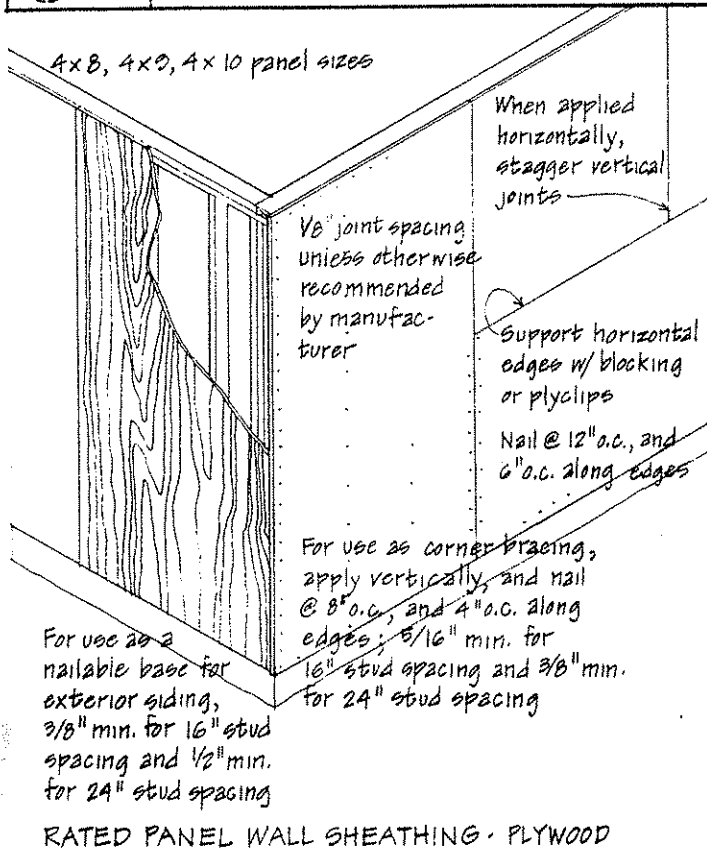
- For spans over 4' wide, header requires 2" min. solid bearing at each end down to floor or bottom plate.
- 1/2" plywood spacers are used with 2x members to match 2x4 or 2x6 stud width.
- For unusual load conditions, header should be engineered as a beam.

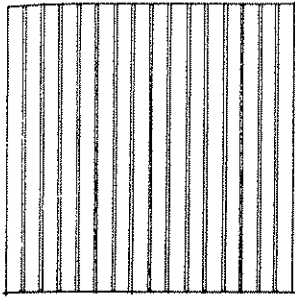


* These lintels should be engineered as beams; verify minimum bearing requirements.

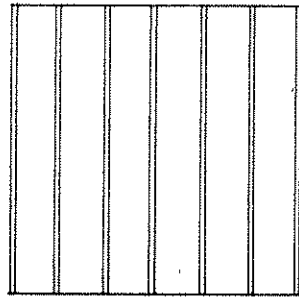
LINTEL OPTIONS FOR WIDE OPENINGS

10 WOOD STUD WALL SHEATHING

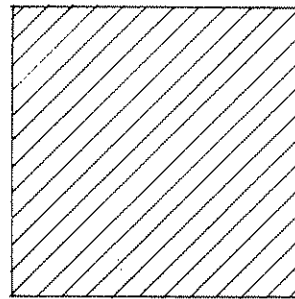




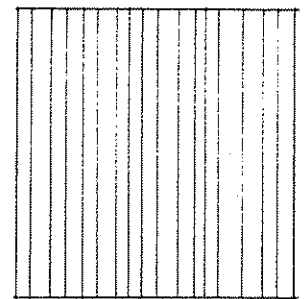
Plywood siding



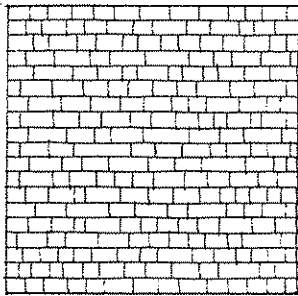
Board and batten



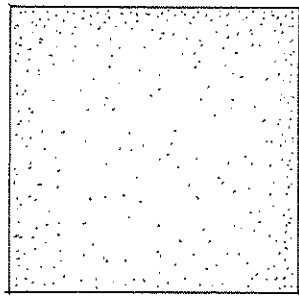
Diagonal board siding



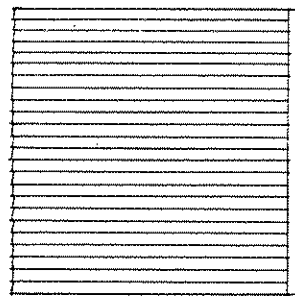
Vertical board siding



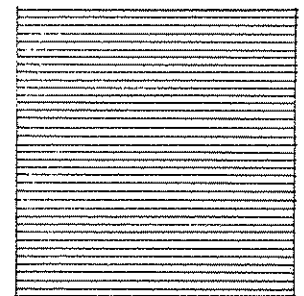
Wood shingles



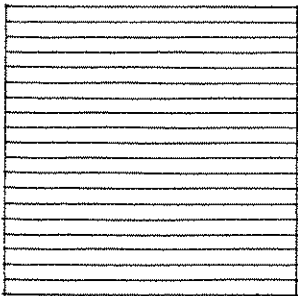
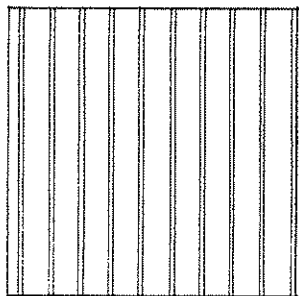
Stucco



Bevel lap siding



Brick veneer

Vinyl or aluminum
siding

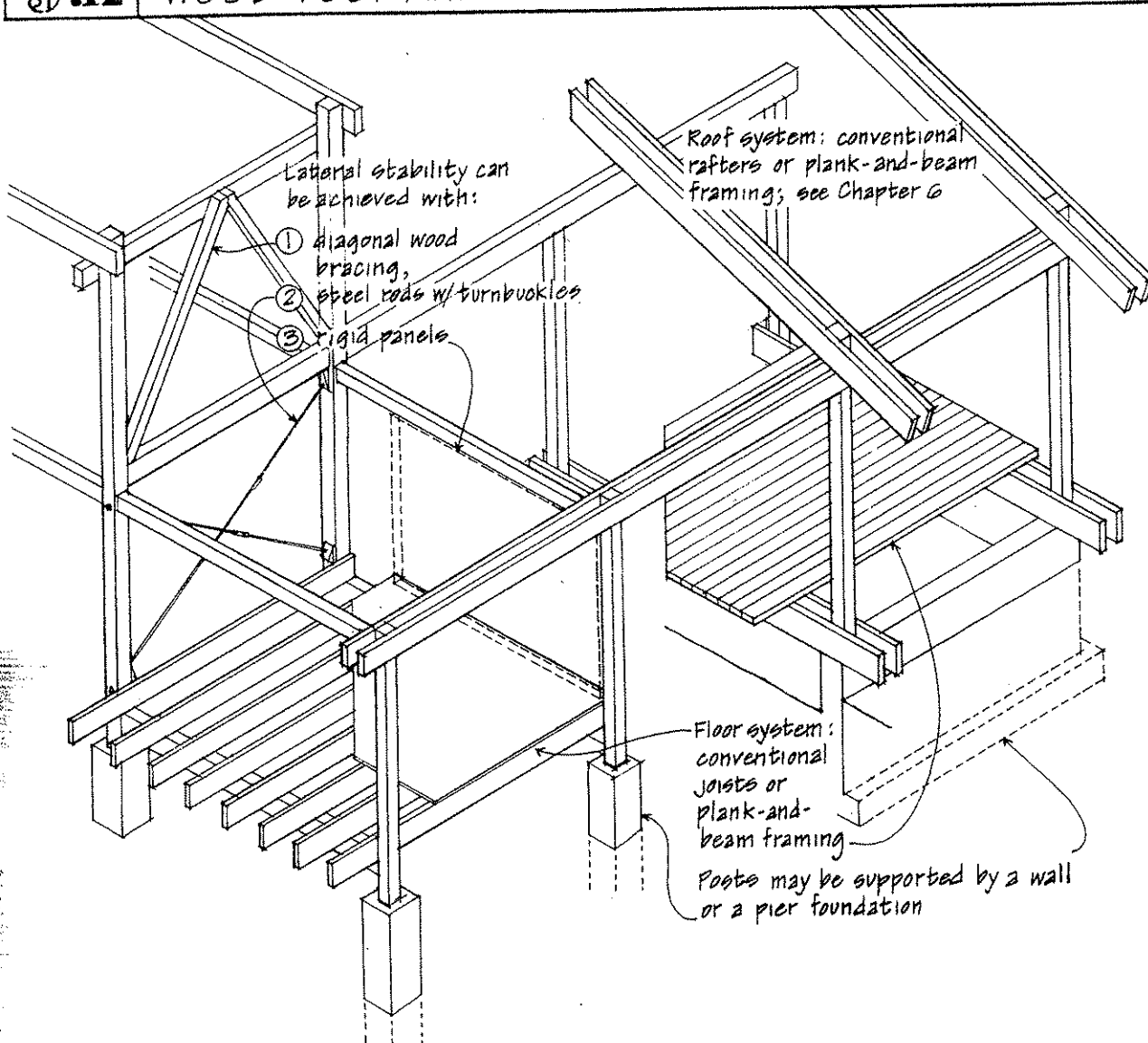
Metal siding

Illustrated on this page are some common finish materials which can be used with wood stud wall framing. Refer to the pages noted for wall section details.

Some factors to consider in the selection of a wall finish material are:

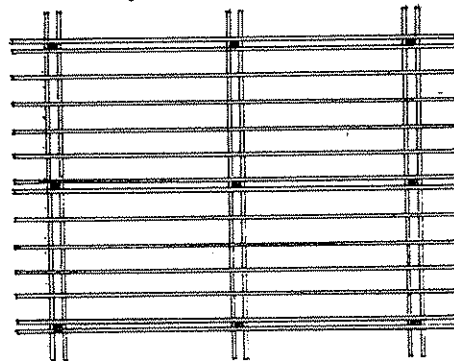
- Stud spacing required
- Sheathing or backing requirements
- Color, texture, pattern, and scale desired
- Standard widths and heights of panel sidings
- Detailing of corners and vertical and horizontal joints.
- Integration of door and window openings into wall pattern
- Durability, maintenance requirements, and weathering characteristics
- Heat conductivity, reflectance, and porosity of the material
- Expansion joints, if required

12 WOOD POST-AND-BEAM FRAMING



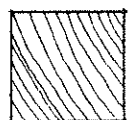
- The beams supporting the floor and roof systems transmit their loads to posts which are supported by the foundation system.
- Together with plank-and-beam floor and roof systems, the post-and-beam wall system forms a three-dimensional grid of spaces which may be expanded vertically or horizontally.
- The skeleton frame of posts and beams is often left exposed to form a visible framework within which wall panels, doors, and windows are integrated.
- When the post-and-beam frame is left exposed, the type of wood used, the careful detailing of the post-and-beam connections, and the quality of workmanship are important factors.

- Column spacing is directly related to the desired bay size and the spanning capability of the beams and floor systems used.

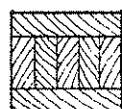


- To qualify as heavy timber or mill construction, members must have a certain thickness. See A.13.

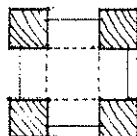
WOOD POSTS AND COLUMNS



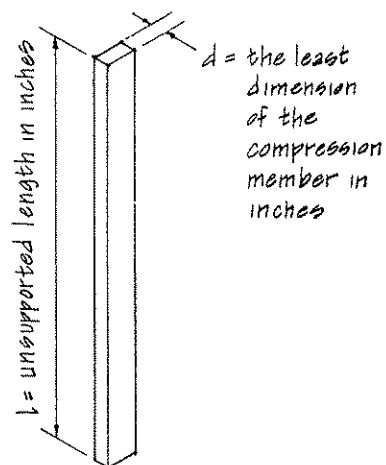
Solid



Built-up



Spaced



Solid columns should be of well-seasoned wood.

Built-up columns may be glue-laminated, or mechanically fastened. Laminated columns may have a higher allowable compressive stress than solid columns, while mechanically fastened columns cannot equal the strength of a solid column of the same dimensions and material.

Spaced columns consist of two or more members separated at their ends and middle points by blocking and joined at their ends by timber connectors and bolts.

- Columns are loaded axially in compression. Failure can result from crushing of the wood fibers if the maximum unit stress exceeds F_c , the allowable unit stress in compression parallel to the grain.
- A column's load capacity is also determined by its slenderness ratio (l/d). As the slenderness ratio increases, a column can fail from buckling.
- $l/d < 50$ for simple solid columns
- $l/d < 80$ for individual members of a spaced column.

The following table is to be used only for the preliminary sizing of solid wood columns.

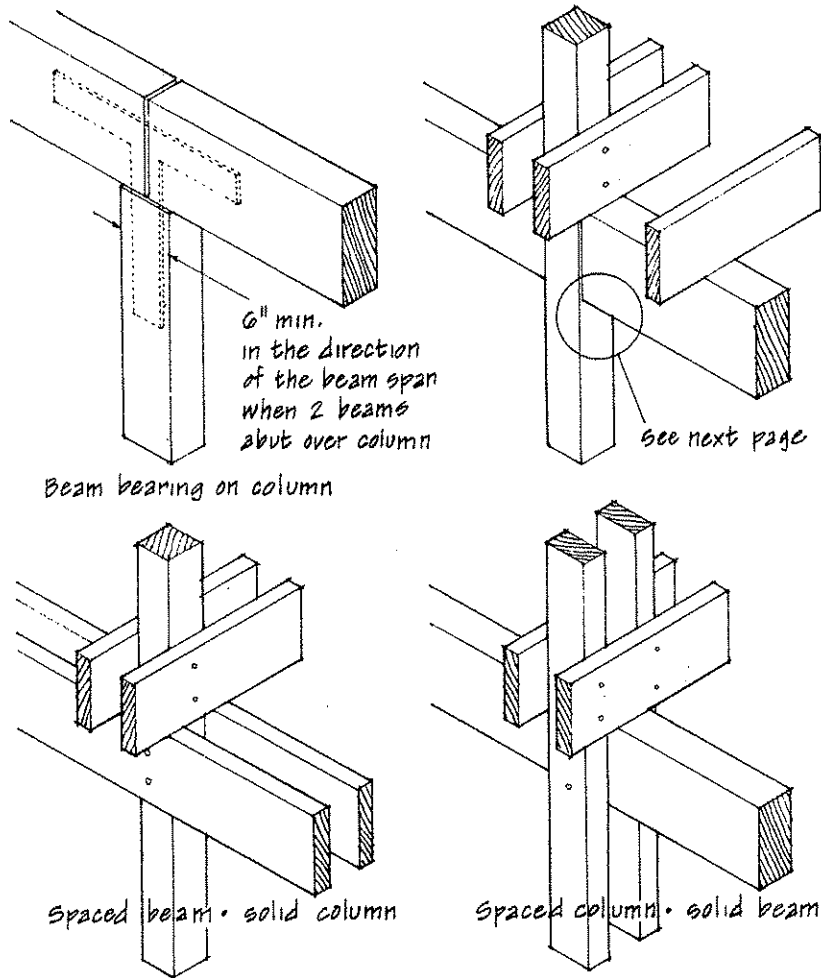
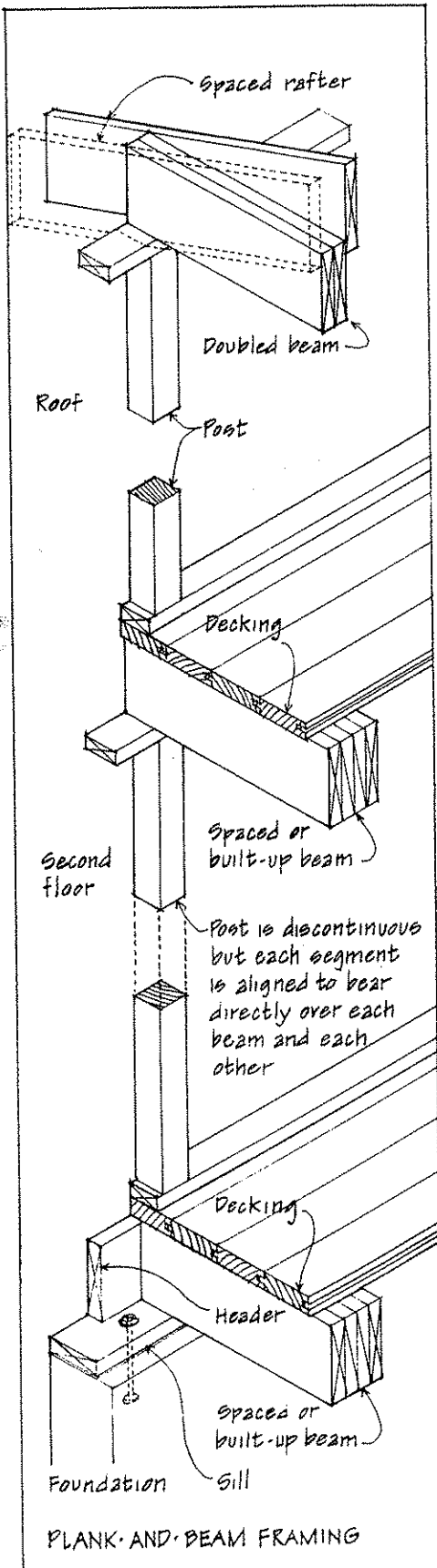
ALLOWABLE AXIAL LOADS FOR SOLID WOOD COLUMNS (in pounds)

Length in feet	Nominal size and resulting P/A *									
	4 x 4	P/A (psi)	4 x 6	P/A (psi)	6 x 6	P/A (psi)	6 x 8	P/A (psi)	8 x 8	P/A (psi)
8	5860	478	9210	478	35,760	1182	47,140	1182	116,285	2209
10	3750	306	5890	306	22,872	756	30,150	756	74,425	1414
12	2605	212	4095	212	15,880	525	20,942	525	51,686	982
14					11,665	386	15,380	386	37,975	721
16					8,935	295	11,776	295	29,071	552
18							9,308	233	22,972	436
20									18,600	353

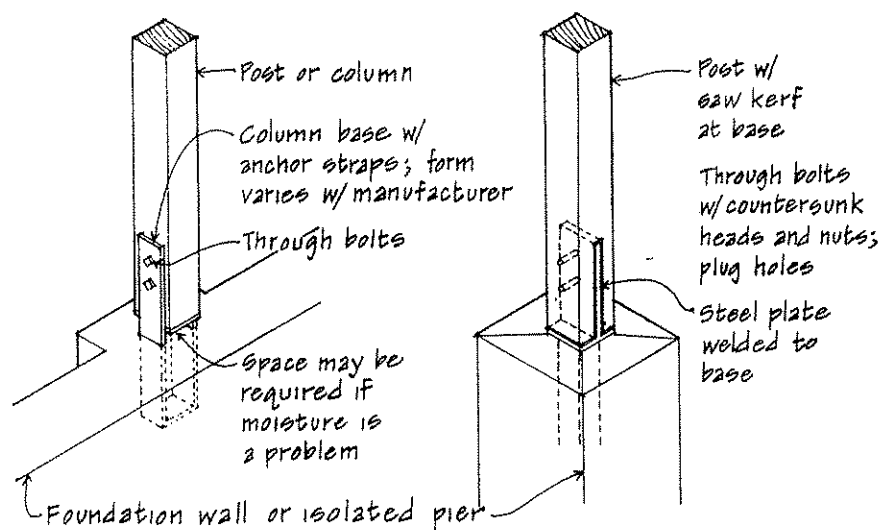
* The above assumes the modulus of elasticity (E) = 1.2×10^6 psi. P/A should not exceed F_c , the allowable unit stress in compression parallel to grain, for the wood used.

V.14

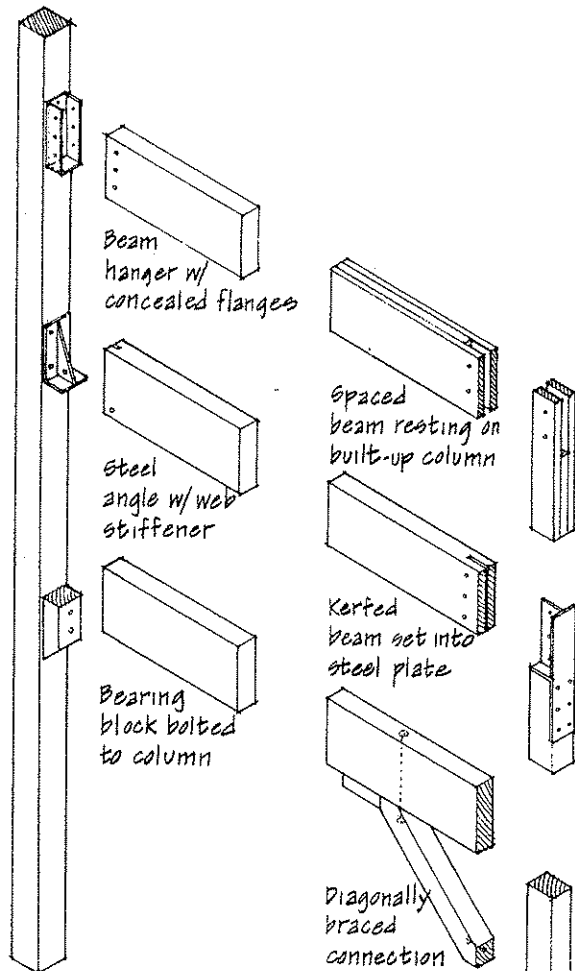
WOOD POST AND BEAM CONNECTIONS



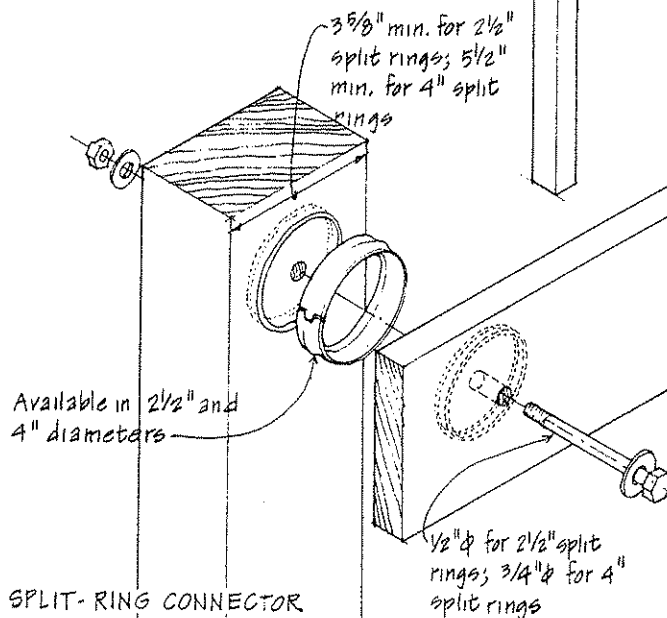
POST-BEAM RELATIONSHIPS - See also 4.16 and 4.17



POST BASE SUPPORTS



COLUMN SUPPORTS FOR BEAMS



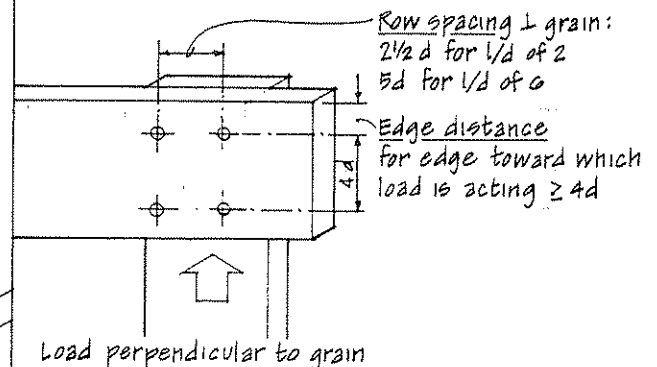
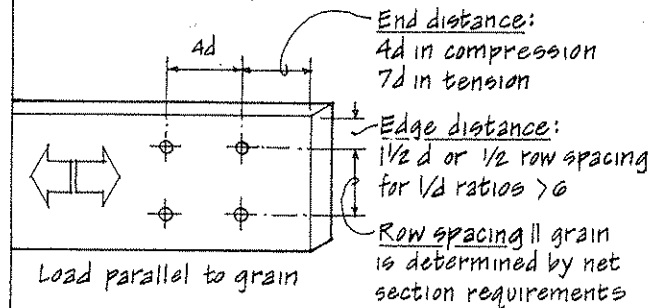
SPLIT-RING CONNECTOR

The strength of a post-and-beam connection depends on:

- the thickness of the wood members
- the species and grade of lumber used
- the angle of the resisting force relative to the grain of the wood
- the size and number of bolts used
- the use, if any, of timber connectors.

The size and number of bolts required for a connection depend on the magnitude of the loads being transferred. Generally, greater efficiency is achieved with a few large bolts rather than with more smaller ones.

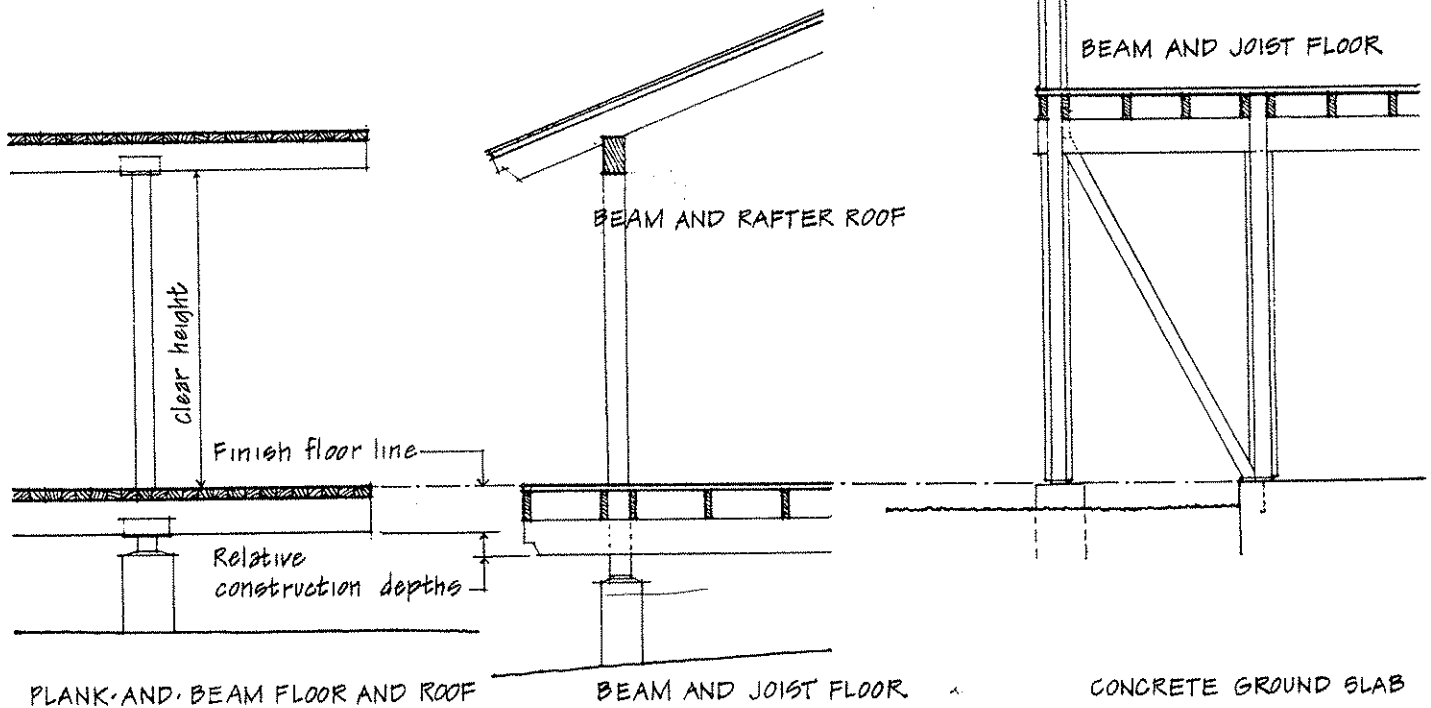
The drawings below illustrate general guidelines for the placement of bolts, according to the bolt diameter (d).



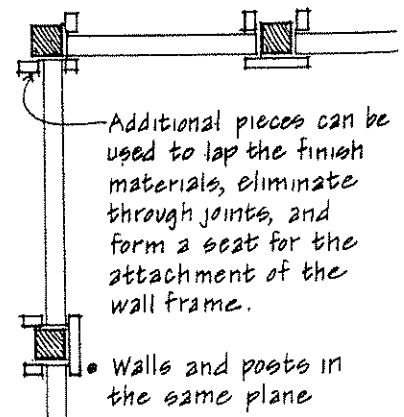
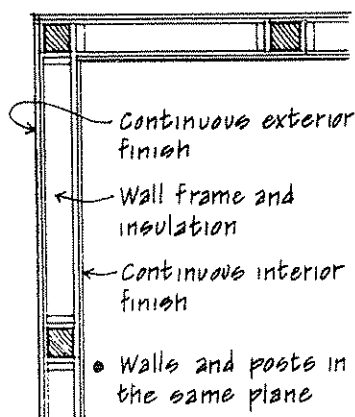
If there is insufficient surface contact area to accommodate the required number of bolts, a split-ring connector can be used. It spreads the load over a larger area of wood and develops higher stresses per unit of bearing than a single bolt alone.

§.16 WOOD POST-AND-BEAM FLOOR AND ROOF CONNECTIONS

These generalized sections illustrate various foundation, floor, and roof system connections to post and beam walls. Note that beams are integral parts of both wall and floor or roof systems. The type of floor and roof systems used and how they are supported by the wood posts or columns affect the construction depth of the floor and roof planes and the overall height of the structure.

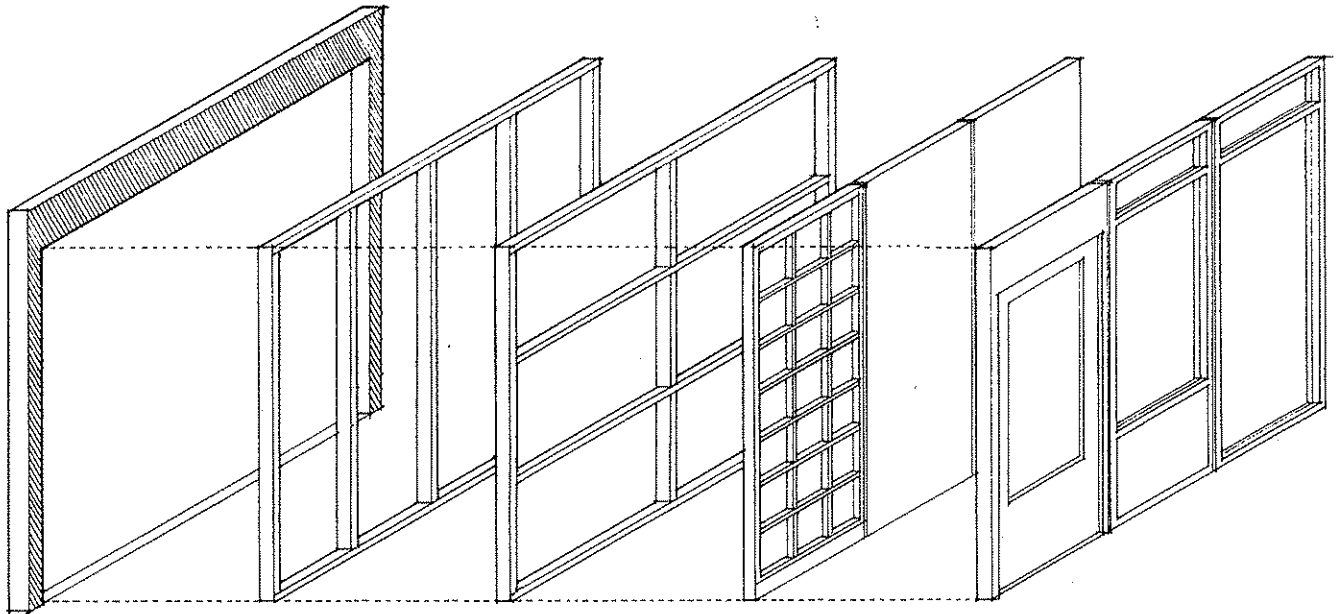


Wall panels can be related to the post and beam frame in a number of ways.



WALL RELATIONSHIPS TO POST-AND-BEAM FRAME

WOOD POST-AND-BEAM WALL PANELS



Post-and-beam frame

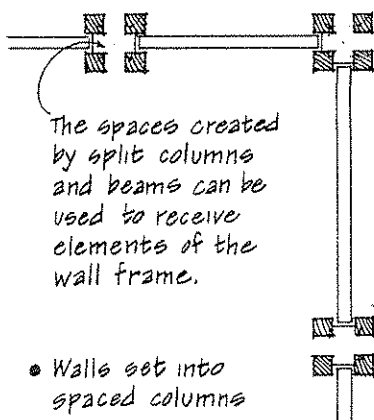
Wood stud framing with its range of finishes; framing may be vertical or horizontal depending on wall finish requirements

Prefabricated composite wall panels

Door and window units

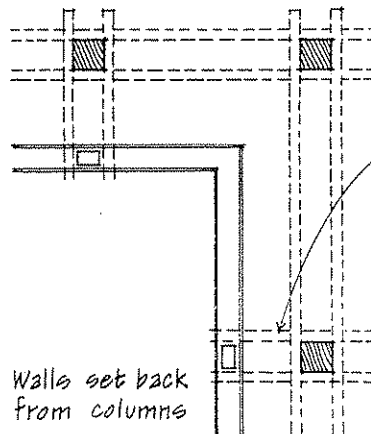
The pattern created by the wall panels should be regulated by the grid established by the post-and-beam framework. Additional factors to consider include:

- The connections between the wall panels and the structural frame must be able to transfer dead, wind, and possibly, bracing loads.
- The tolerances required for the installation of the wall panels must be built into the joint details.
- The joint details should also provide for a weathertight seal through the use of offsets, flashing, or caulking.
- Allowance should be made for movement of exposed wood due to changes in moisture content, and, when joining dissimilar materials, for different rates of thermal expansion and contraction.

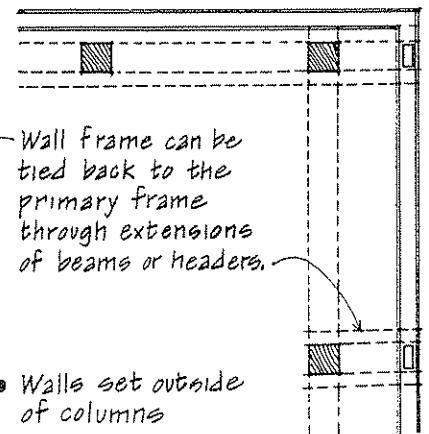


The spaces created by split columns and beams can be used to receive elements of the wall frame.

- Walls set into spaced columns



- Walls set back from columns

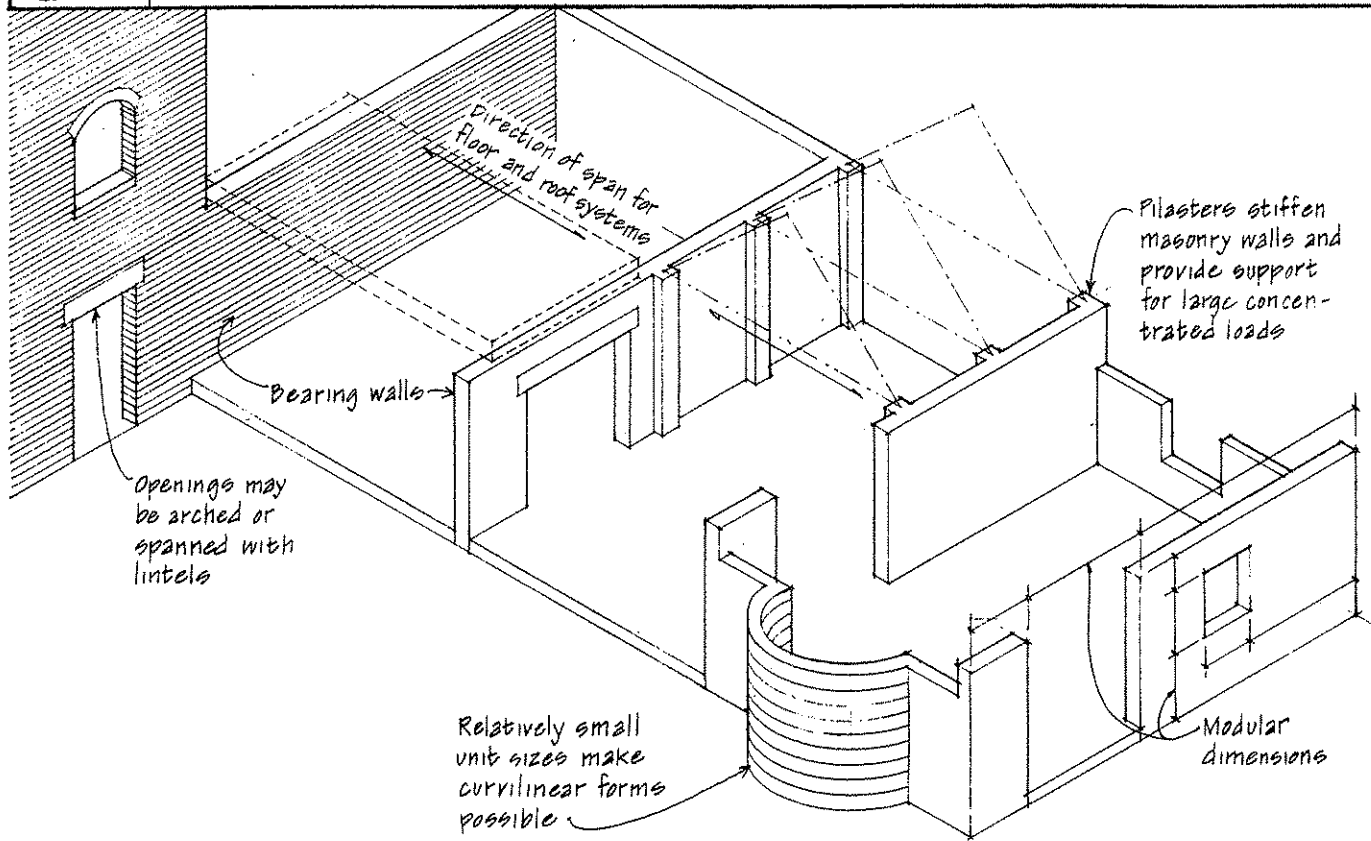


- Walls set outside of columns

WALL RELATIONSHIPS TO POST-AND-BEAM FRAME

5.18

MASONRY WALL SYSTEMS



Masonry walls consist of modular building blocks bonded together with mortar to form walls which are structurally most efficient in compression.

The most common types of masonry units are

- Brick, a heat-hardened clay unit
- Concrete block, a chemically-hardened unit

Other types of masonry units include structural clay tile, structural glass block, and natural or cast stone.

- Masonry bearing walls are typically arranged in parallel sets to support wood, steel, or concrete spanning systems.
- Masonry walls provide strong spatial definition and enclosure, weather protection, and an integral and durable wall finish with a single material
- Differential movements in masonry walls due to changes in temperature or moisture content, or to stress concentrations, require the use of expansion and control joints.
- Water penetration through porous masonry materials must be controlled through the use of tooled joints, cavity spaces, flashing, and caulking.
- For fire-resistance ratings of masonry walls, see A.13.

To minimize cutting and for appearance, the major dimensions of masonry walls should be based on the size of the modular units used.

Grid lines @ 8" o.c. for standard concrete block		
2 2/3" units	3 1/2" units	4" units

Standard modular, Norman, SCR brick	Engineer, Norwegian, 6" Norwegian	Economy, Jumbo utility, 6" and 8" Jumbo
---	---	---

Relative Course Heights (Nominal)

- For lengths, use multiples of 4", 8", or 12"
- Wall thicknesses vary with type wall; see 5.20
- For thermal insulation, see 8.25.

MASONRY WALLS

MINIMUM THICKNESS OF MASONRY WALLS

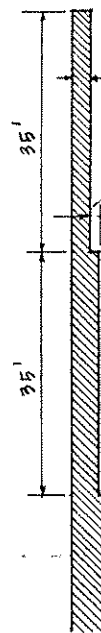
Type of masonry (see 5.20 - 5.22)	Max. ratio of UL or UH to T*	Min. thickness (nominal)
Bearing walls:		
Stone masonry	14	16"
Cavity wall masonry	18	8"
Hollow unit masonry	18	8"
Solid masonry	20	8"
Grouted masonry	20	6"
Reinf. masonry	25	6"
Nonbearing walls:		
Ext. unreinforced	20	See note below
Ext. reinforced	30	
Int. unreinforced	36	2"
Int. reinforced	48	2"

Exterior nonbearing walls may be 4" less than required for bearing walls, but not less than 8" thick, except where 6" walls are permitted in residences.

* UL = Unsupported length between cross walls, piers, or attached columns

UH = Unsupported height between floors or between floor and roof.

Sufficient bonding or anchorage is required to transfer loads from masonry wall to its supports



PLAIN MASONRY BEARING WALLS

Plain (unreinforced) masonry bearing walls must be at least 12" thick for the uppermost 35' of the wall and increase 4" in thickness for each successive 35' downward from the top.

Unreinforced grouted masonry may be 2" less than noted above, but no less than 6" thick.

For buildings not more than 3 stories or 35' in height, masonry walls may be 8" thick.

One-story solid masonry walls not more than 9' high may be 6" thick.

Note: Consult a structural engineer and local building codes to verify the structural requirements for masonry walls.

ALLOWABLE COMPRESSIVE STRESSES IN UNREINFORCED MASONRY WALLS (psi)

Material	Type M	Type S	Type N
Solid brick			
4500+ psi	250	225	200
2500-4500 psi	175	160	140
Solid concrete units			
Grade N	175	160	140
Grade S	125	115	100
Grouted masonry			
4500+ psi	350	275	Not permitted
2500-4500 psi	275	215	
Cavity walls			
Solid units	140	130	110
Hollow units	70	60	50
Hollow units	170	150	140
Natural stone	140	120	100

MORTAR is used to join masonry units together, bond reinforcing steel to the masonry, and seal the masonry wall against wind and rain penetration. It consists of Portland or masonry cement, hydrated lime, aggregate, and water.

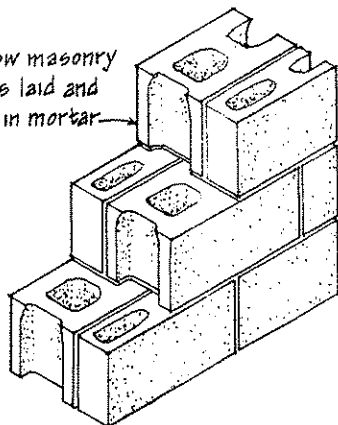
Type M - A high-strength mortar for masonry walls below grade, and walls subject to high lateral or compressive loads or to severe frost action.

Type S - A medium-high-strength mortar for walls where bond and flexural strength are more important than high compressive strength.

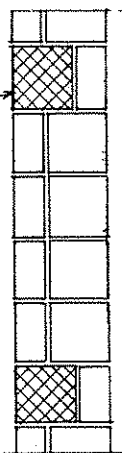
Type N - A medium-strength mortar for general use above grade.

Type O - A low-strength mortar for interior nonbearing partitions.

Hollow masonry units laid and set in mortar.



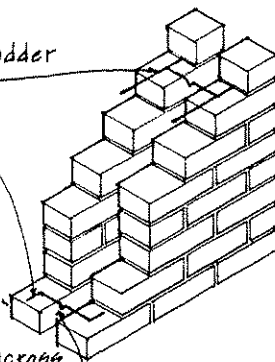
When wall thickness is made up of 2 or more units, bond stretcher courses @ vertical intervals not exceeding 34" w/ units lapping at least 4" over unit below; vertical spacing not to exceed 17" if bonding units are at least 50% greater in thickness than units below.



Wall may also be bonded w/ metal ties as in cavity walls, except that max. vertical distance between ties should not exceed 18".

2-wire ladder tie or Z-tie.

Drip to prevent water from running across tie to inner wythe.



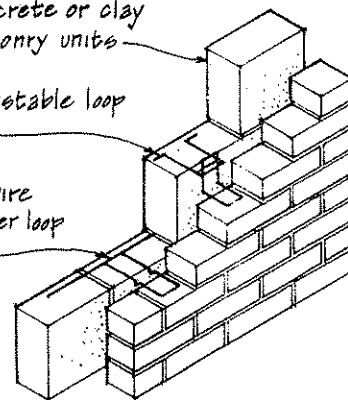
Provide a metal tie for each $4\frac{1}{2}$ S.F. of wall area for cavities up to $3\frac{1}{2}$ " wide; for wider cavities, provide a metal tie for each 3 S.F. of wall area.

Both facing and backing wythes to be at least 4" thick.



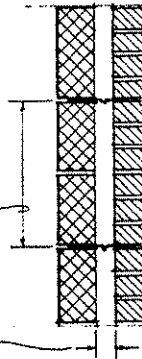
Concrete or clay masonry units.

Adjustable loop tie or 2-wire ladder loop tie.



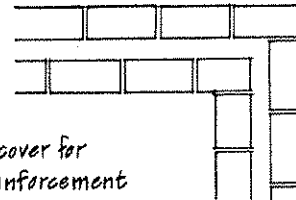
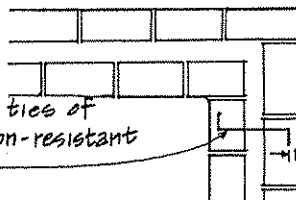
Stagger ties in alternate courses w/ a max. vertical distance between ties of 24" and a max. horizontal spacing of 36".

Cavity to be not less than 1" nor more than 4" wide.



$\frac{3}{16}$ " ϕ ties of corrosion-resistant metal.

$\frac{5}{8}$ " min. mortar cover for joint reinforcement.



• HOLLOW UNIT MASONRY

Hollow unit masonry walls consist of hollow clay or concrete masonry units laid and set in mortar. When the wall thickness is made up of two or more units, the stretcher courses must be bonded with masonry headers or metal ties. When bonded with metal ties, the wall must conform to the thickness and height requirements of cavity walls.

• CAVITY WALL MASONRY

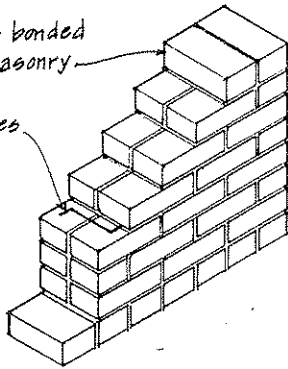
Cavity wall masonry is made up of a facing and a backing wythe of brick, structural clay tile, or concrete masonry units. The two wythes are completely separated by an air space except for the metal ties which are required for bonding.

When computing the ratio of unsupported height or length to thickness, the value for thickness is equal to the sum of the nominal thicknesses of the inner and outer wythes.

Cavity walls have two advantages over other types of masonry walls:

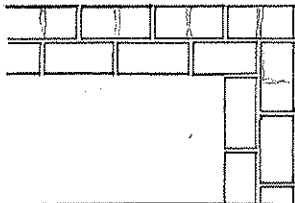
- ① The cavity enhances the insulation value of the wall and permits the installation of additional thermal insulation material.
- ② The air space acts as a barrier against water penetration if the cavity is kept clear, and if adequate weep holes and flashing are provided.

Wall may be bonded w/ either masonry headers or w/ metal ties



Masonry headers to compose at least 4% of exposed face area, with a vertical and horizontal spacing of not less than 24".

Metal ties may be used to bond wall if they conform to requirements for cavity walls.

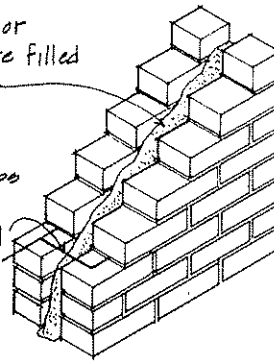


• SOLID MASONRY

Solid masonry walls may be of brick, concrete brick, or solid load-bearing concrete masonry units. Adjacent wythes in both bearing and nonbearing walls may be bonded with either masonry headers or metal ties. Metal ties are preferred over masonry headers for better resistance to rain penetration and allowance for slight differential movement between the wythes.

All interior joints are filled w/ grout

Water drips are not permitted

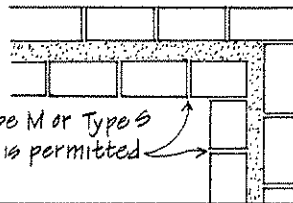


3/4" min. for low-lift grout construction

3" min. for high-lift grout construction w/ rectangular-shaped metal ties spaced no more than 24" apart horizontally and 16" vertically (12" vertical spacing for stack bond)



Only Type M or Type S mortar is permitted



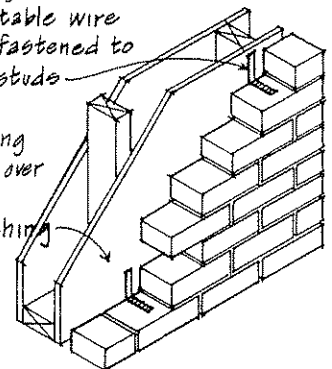
• GROUTED MASONRY

Grouted masonry walls consist of brick or solid concrete brick units in which the interior joints are filled with grout as the work progresses.

In low-lift grout construction, the wall is grouted in lifts not to exceed 8". In high-lift construction, grouting is done in lifts not to exceed 6'. High-lift construction therefore requires a wider grout space and rigid metal ties to bond the two tiers together.

Corrugated metal or adjustable wire ties fastened to wall studs

Building paper over wall sheathing



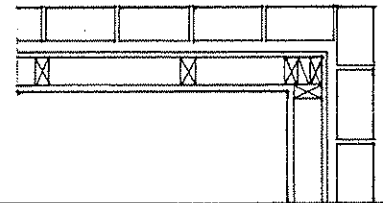
Masonry veneer

1" air space

Building paper over wall sheathing

Wood or metal stud wall frame

Metal ties spaced no more than 16" horizontally and 24" vertically

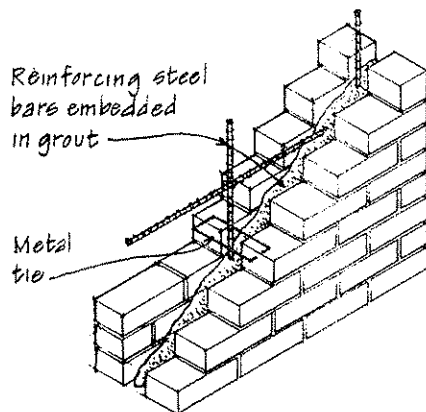


• MASONRY VENEER

In masonry veneer construction, a single wythe of masonry serves as a weather barrier and is anchored (but not bonded) to a structural frame.

In residential construction, wood or metal stud walls are typically faced with brick or stone veneers.

Masonry veneers can also be used as curtain walls supported by steel or concrete frames.

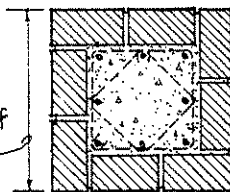
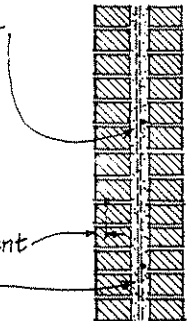


$\frac{1}{4}$ " min. mortar or grout cover between reinforcement and masonry; #2 bars may be placed in $\frac{1}{2}$ " horizontal joints

$\frac{5}{8}$ " min. mortar cover for horizontal joint reinforcement

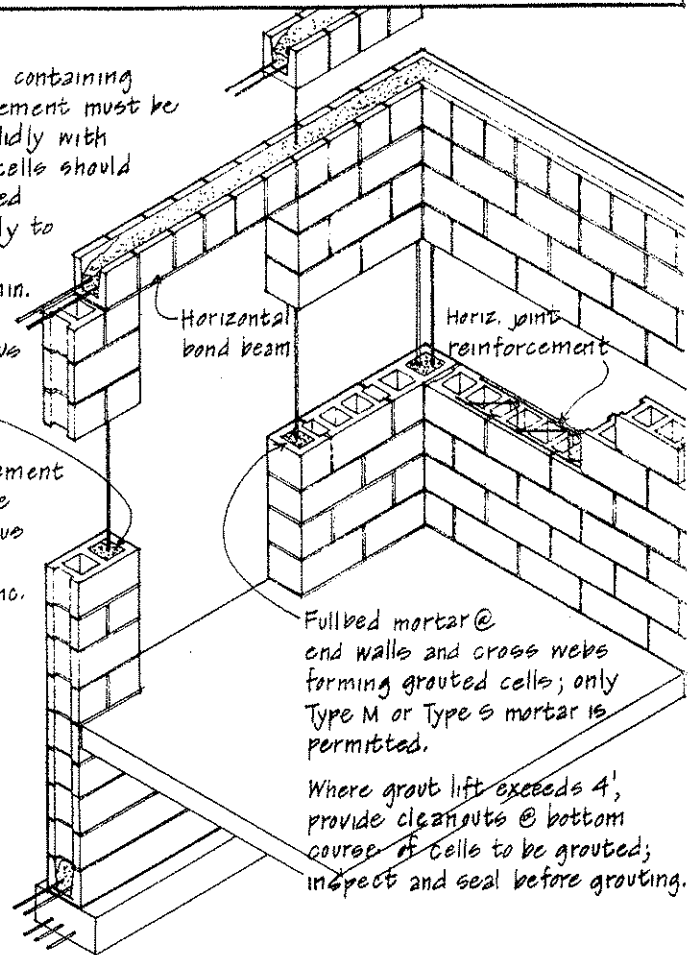
Portland cement grout

Least dimension of reinforced masonry columns to be 12" with an unsupported length of 20 x least dimension



All cells containing reinforcement must be filled solidly with grout; cells should be aligned vertically to form a 2" x 3" min. clear, continuous vertical space

Reinforcement should be continuous down to reinf. conc. footing



REINFORCED GROUTED MASONRY

Reinforced grouted masonry should conform to the requirements for plain grouted masonry. See 5.21.

REINFORCED HOLLOW UNIT MASONRY

Reinforced hollow unit masonry consists of hollow masonry units in which certain cells contain reinforcing steel fully embedded in concrete or portland cement grout.

General Notes:

Load-bearing masonry walls may be plain (unreinforced), partially reinforced, or reinforced. Reinforced masonry walls are similar to reinforced concrete walls. They use standard deformed reinforcing steel bars, fully embedded in grout, for increased resistance to buckling and lateral wind and seismic loads. It is essential that a strong bond develop between the reinforcing steel, grout, and masonry units.

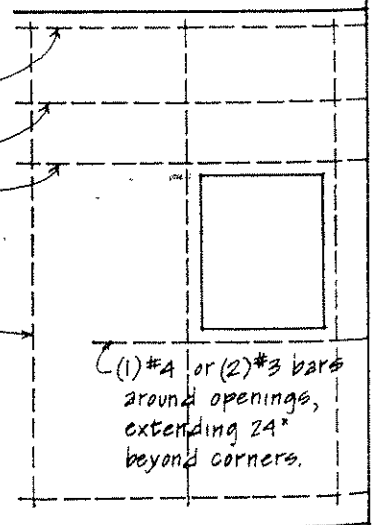
Consult a structural engineer and local building code requirements for the design of reinforced masonry walls.

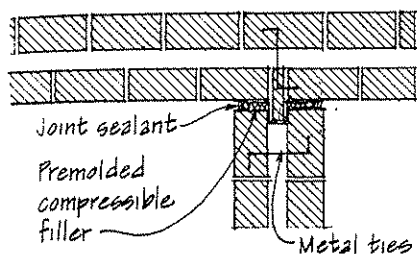
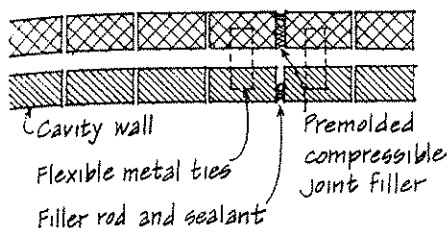
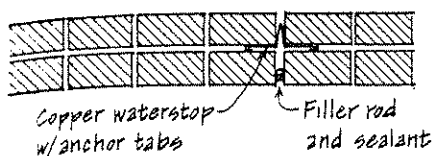
Provide horizontal reinforcement:

- at top of parapet walls,
- at structurally connected floors and roofs,
- at top of wall openings,
- in the top of footings.

Reinforcement to be $\frac{3}{8}$ " ϕ min., with a maximum spacing of 4' o.c.

The sum of vertical and horizontal reinforcement to be at least 0.002 x the gross cross-sectional area of the wall.



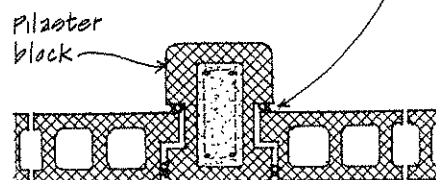
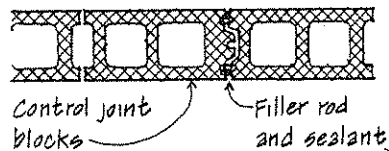
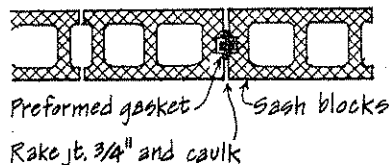
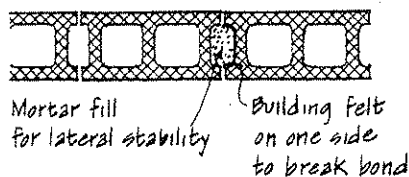
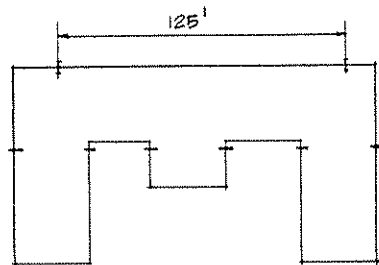


* For expansion joint sizes, see 8.28

Expansion joints should be weathertight and allow movement in the plane of the wall.

EXPANSION JOINTS

Masonry materials expand and contract with changes in temperature and moisture content. Expansion joints allow this movement to occur in a masonry wall by providing a complete separation through the structure. They should generally be located at 125' intervals along unbroken wall lengths, and at offsets and corners of U, L, and T shaped buildings.



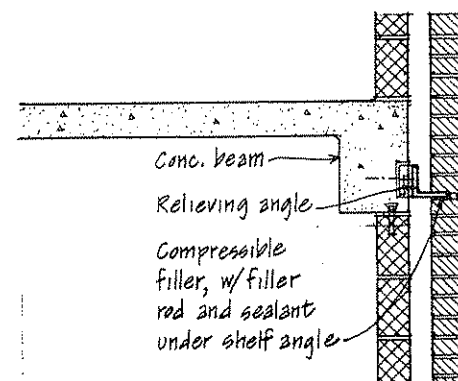
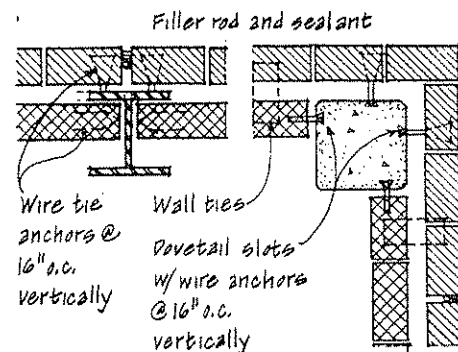
Control joints should be weathertight and provide lateral stability across the joint.

CONTROL JOINTS

A concrete masonry wall is subject to shrinkage as it dries after construction. Shrinkage cracking can be controlled by using Type 1 moisture-controlled concrete masonry units, reinforcing horizontal joints, and properly placing control joints.

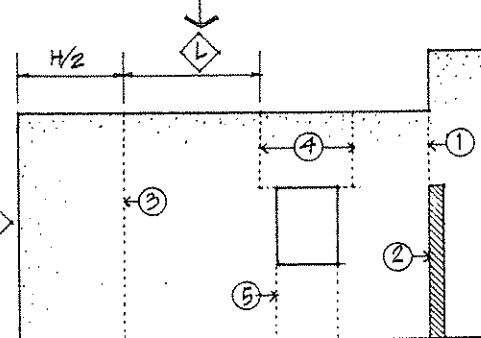
Control joints are also used to control cracking where points of weakness or stress concentration are expected:

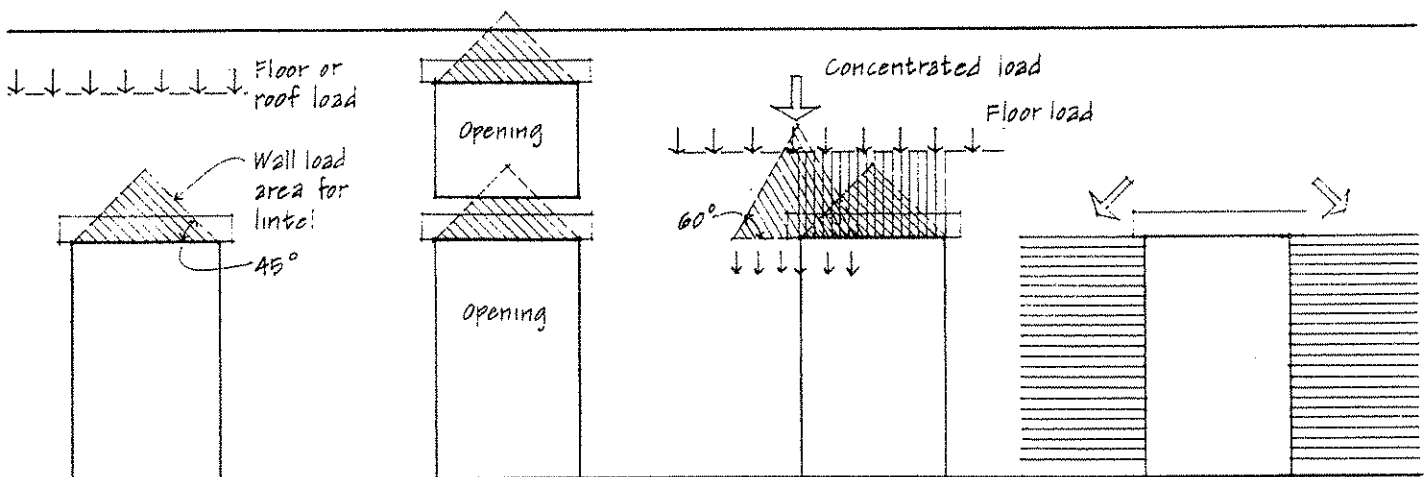
- ① at changes in wall height or thickness
- ② at columns, pilasters, and wall intersections
- ③ near corners
- ④ both sides of openings > 6'
- ⑤ one side of openings < 6'



Vertical and horizontal control joints are required between steel or concrete frames and supported masonry walls or panels.

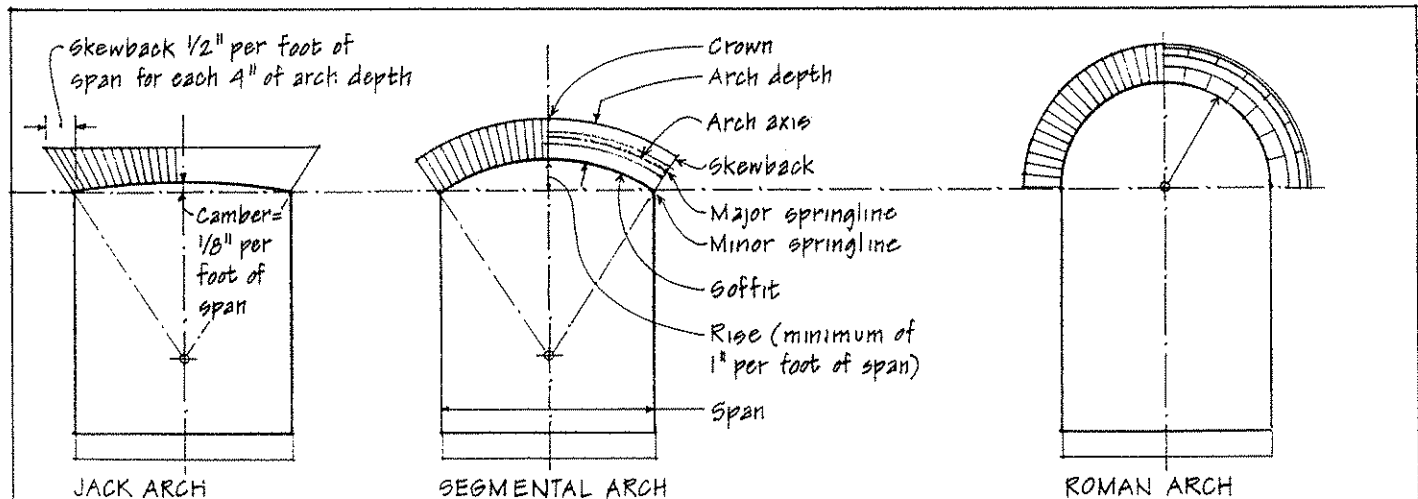
Control Joint Spacing w/ Type 1 units	Vertical Spacing of Joint Reinforcement	
	16"	8"
Wall length (L) between control jts.	50'	60'
L/H ratio	3	4



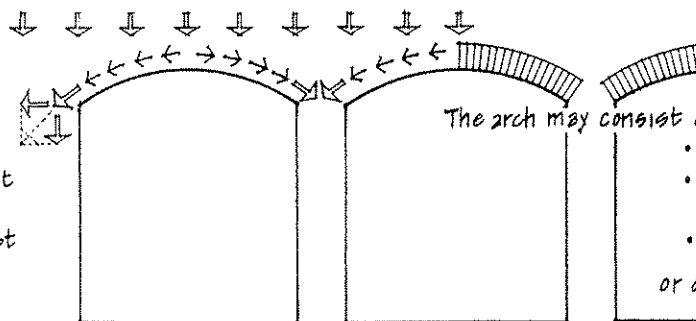


- Arching action of masonry above opening supports wall load outside of load triangle.
- Lintel carries less wall load than normal load triangle.
- Lintel must carry an additional load if a concentrated load or floor or roof loads fall within normal load triangle.
- Horizontal thrust from any arching action must be resisted by the wall mass on either side of the opening.

LOADS ON LINTELS



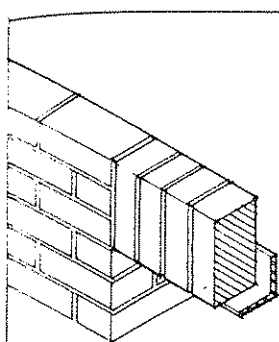
The horizontal thrust of the arching action must be resisted by the mass of the wall adjacent to the opening or by an equal but opposite thrust from an adjoining arch.



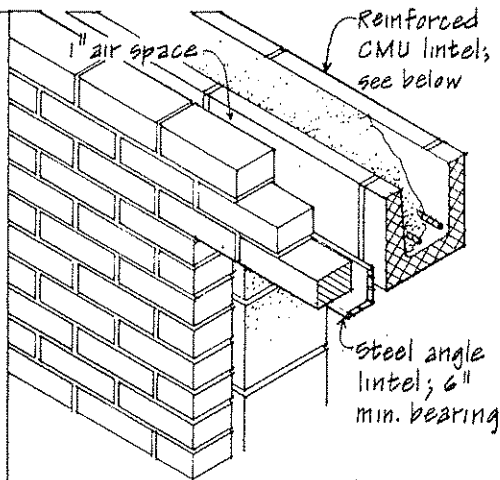
- The arch may consist of brick:
- 2 soldier course
 - alternating soldier and rowlock courses
 - 2 or 3 rowlock courses...
- or of stone.

MASONRY ARCHES utilize the compressive strength of brick and stone to span openings.

LINTELS



Lintel may be visually articulated with a soldier course.

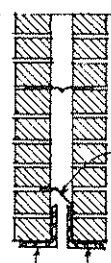


STEEL ANGLE LINTELS

Reinforced CMU lintel; see below

1" air space

steel angle lintel; 6" min. bearing

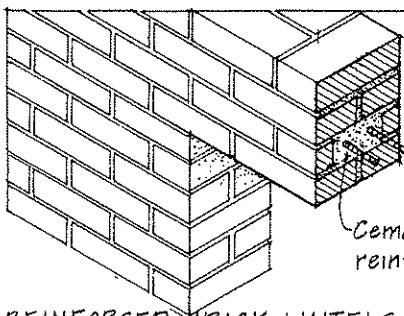


Cavity Wall

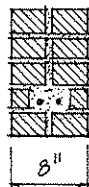


Veneer Wall

Clear span (8" wall)	Exterior angle (no floor load)	Interior angle (500 lbs. floor load per foot of span)
4'	L 3 1/2 x 3 1/2 x 5/16	L 3 1/2 x 3 1/2 x 5/16
5'	L 3 1/2 x 3 1/2 x 5/16	L 5 x 3 1/2 x 5/16
6'	L 4 x 3 1/2 x 5/16	L 5 x 3 1/2 x 3/8



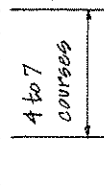
REINFORCED BRICK LINTELS



8"

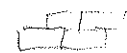


10"

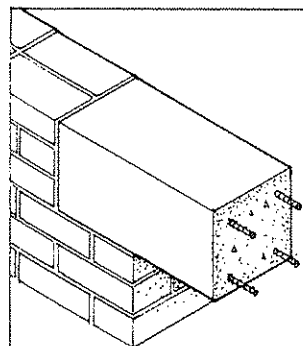


12"

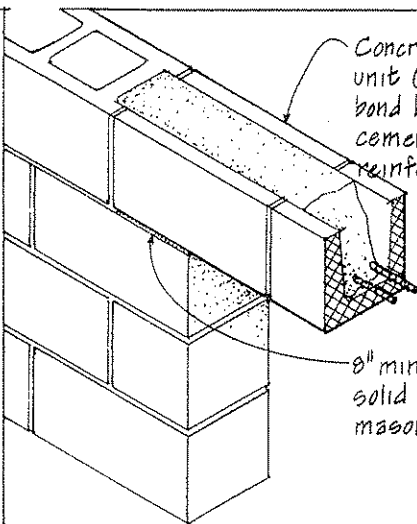
Cement grout and reinforcing steel



4 to 7 courses

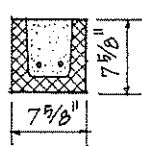


Precast reinforced concrete lintels may be used with both brick and concrete walls.

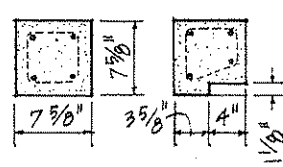


PRECAST CONCRETE AND CMU LINTELS

Concrete masonry unit (CMU) lintel or bond beam block w/ cement grout fill + reinforcing steel



CMU

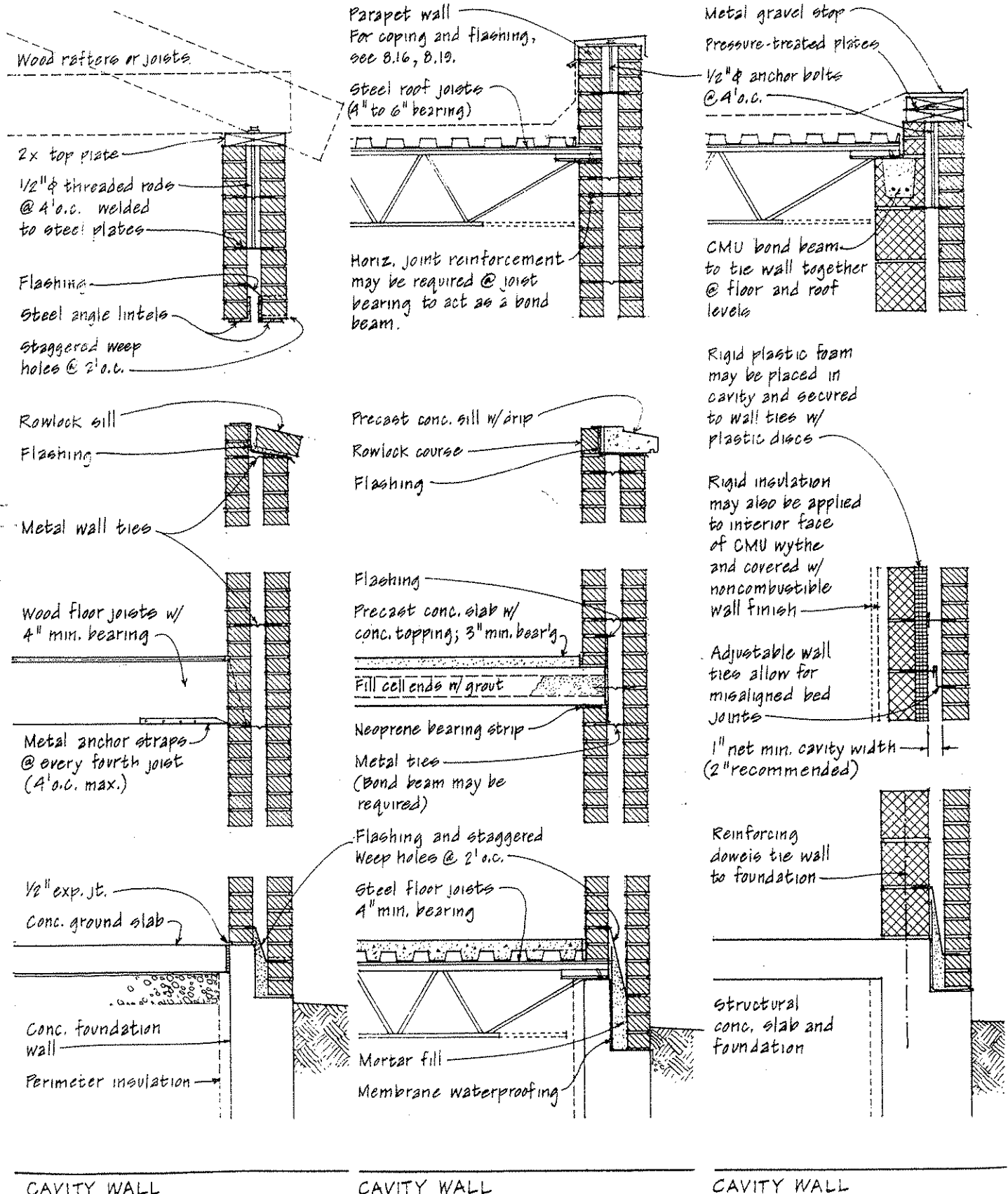


Precast Concrete

Reinforcing for lintels in 8" masonry wall (80 lbs./SF) w/ no superimposed loads		
Lintel type	Clear span	Nº/Size
7 5/8" square reinf. conc. lintel	4'	4 #3
	6'	4 #4
	8'	4 #5
8x8x16 nominal CMU lintel	4'	2 #4
	6'	2 #5
	8'	2 #6

V^o 26

BRICK WALL SECTIONS

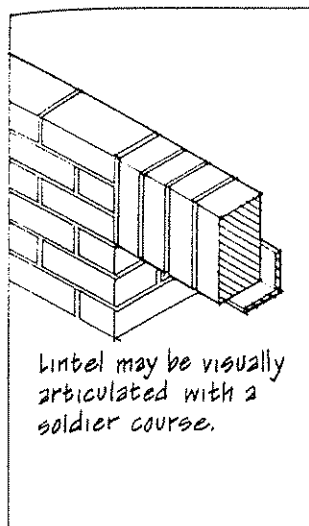


CAVITY WALL

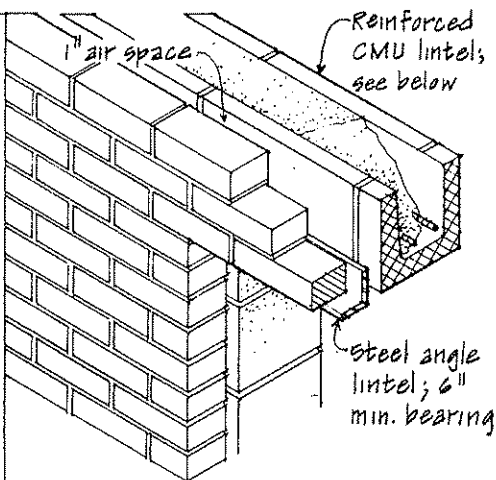
CAVITY WALL

CAVITY WALL

LINTELS



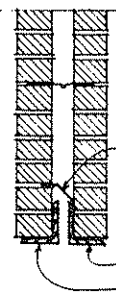
Lintel may be visually articulated with a soldier course.



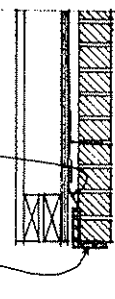
STEEL ANGLE LINTELS

Reinforced CMU lintel; see below

steel angle lintel; 6" min. bearing

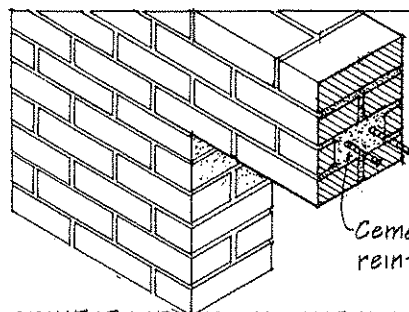


Cavity Wall



Veneer Wall

Clear span (8" wall)	Exterior angle (no floor load)	Interior angle (500 lbs. floor load per foot of span)
4'	L 3 1/2 x 3 1/2 x 5/16	L 3 1/2 x 3 1/2 x 5/16
5'	L 3 1/2 x 3 1/2 x 5/16	L 5 x 3 1/2 x 5/16
6'	L 4 x 3 1/2 x 5/16	L 5 x 3 1/2 x 3/8



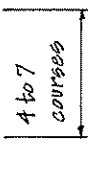
REINFORCED BRICK LINTELS



8"



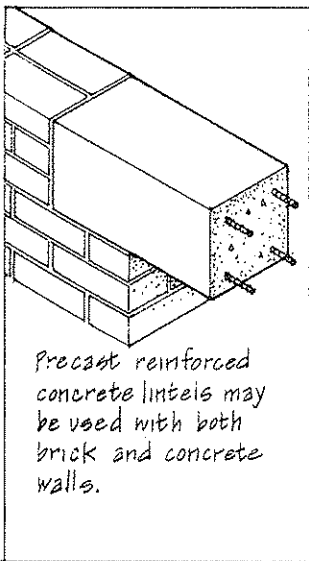
10"



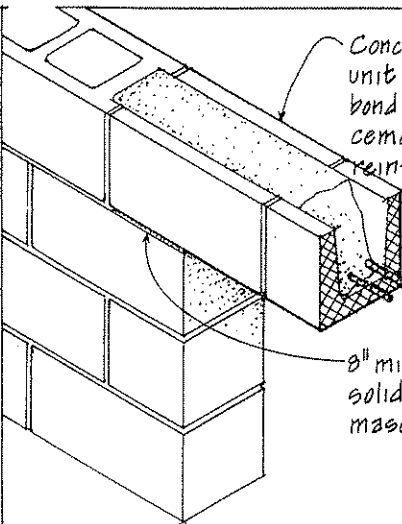
12"

4 to 7 courses

Cement grout and reinforcing steel

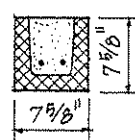


Precast reinforced concrete lintels may be used with both brick and concrete walls.

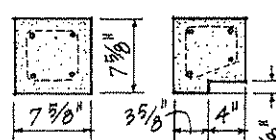


Concrete masonry unit (CMU) lintel or bond beam block w/ cement grout fill + reinforcing steel

8" min. bearing on solid or grouted masonry



CMU



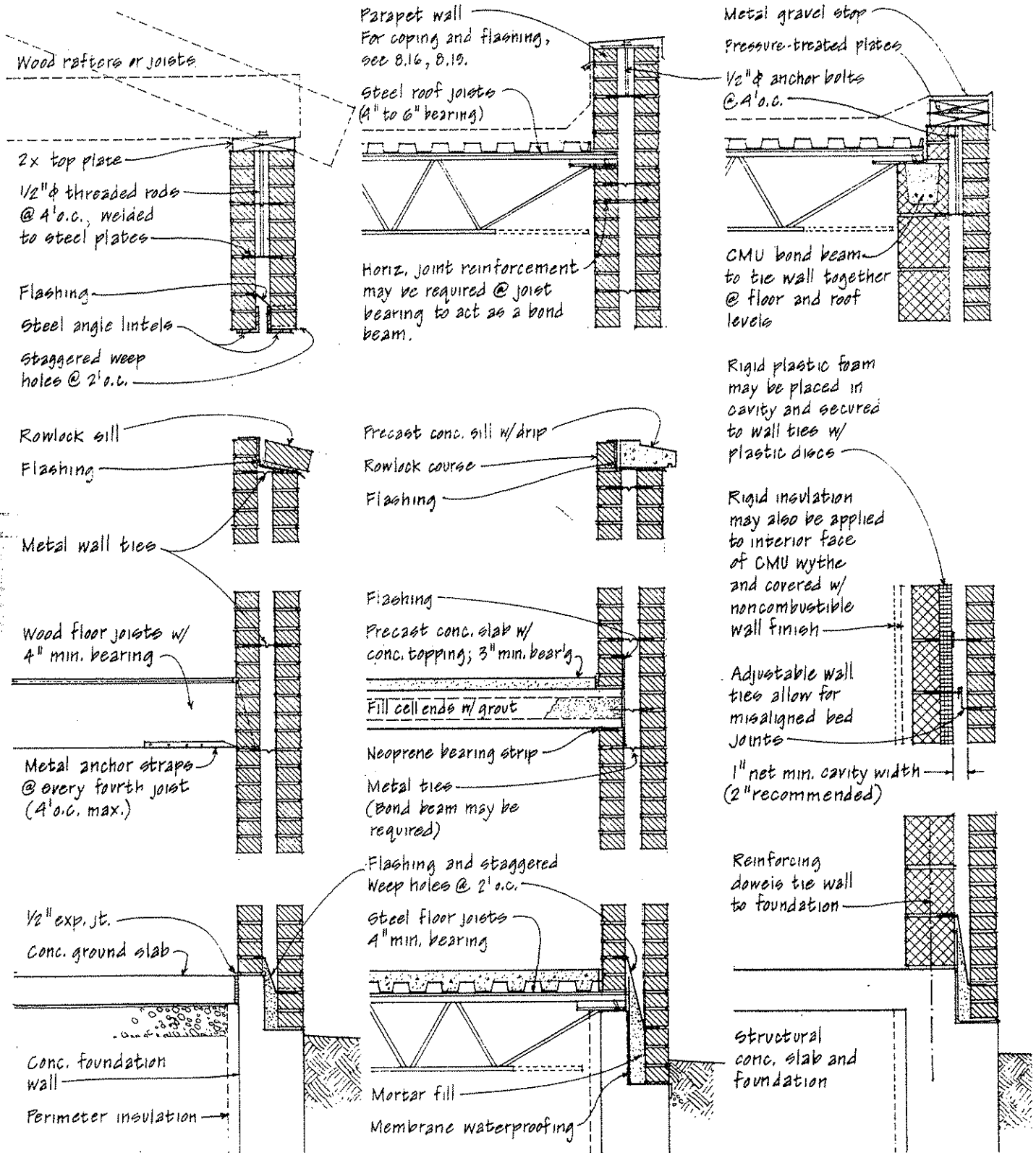
Precast Concrete

Reinforcing for lintels in 8" masonry wall (80 lbs./SF) w/ no superimposed loads		
Lintel type	Clear span	Nº/Size
7 5/8" square reinf. conc. lintel	4'	4 #3
	6'	4 #4
	8'	4 #5
8x8x16 nominal CMU lintel	4'	2 #4
	6'	2 #5
	8'	2 #6

PRECAST CONCRETE AND CMU LINTELS

V.D. 26

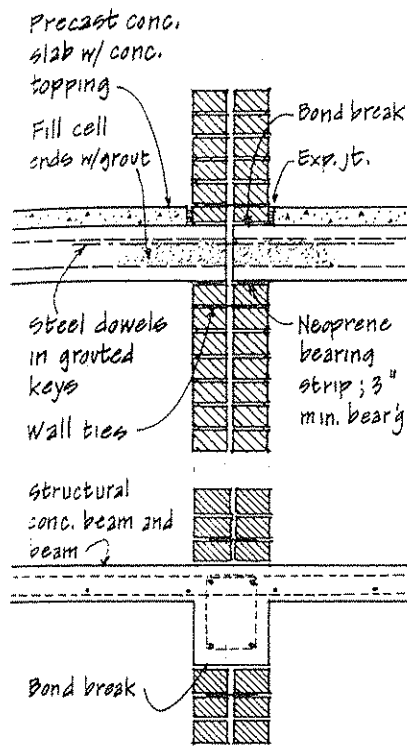
BRICK WALL SECTIONS



CAVITY WALL

CAVITY WALL

CAVITY WALL



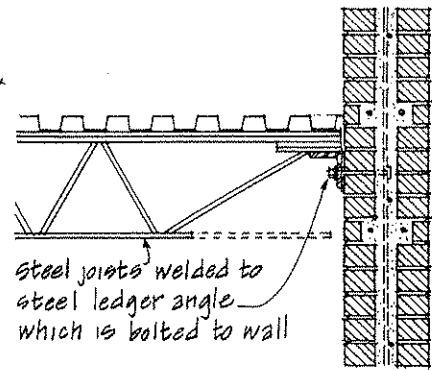
Wood rafters or joists

2x top plate w/ 1/2" anchor bolts @ 4' o.c.

Horiz. reinforcement to form bond beam

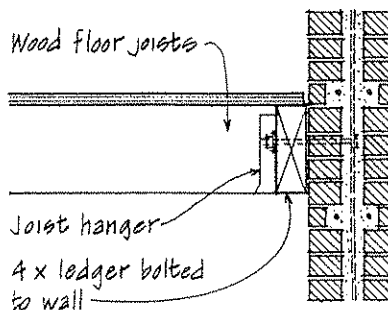
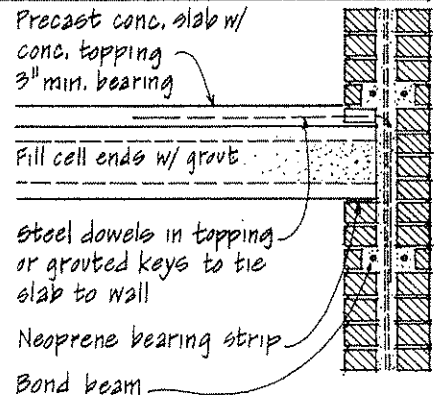
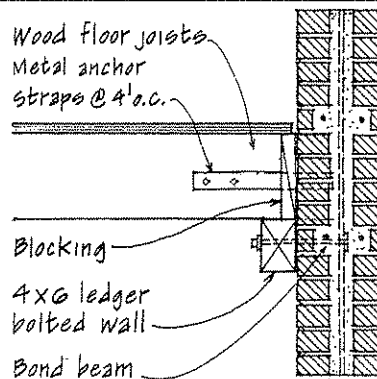
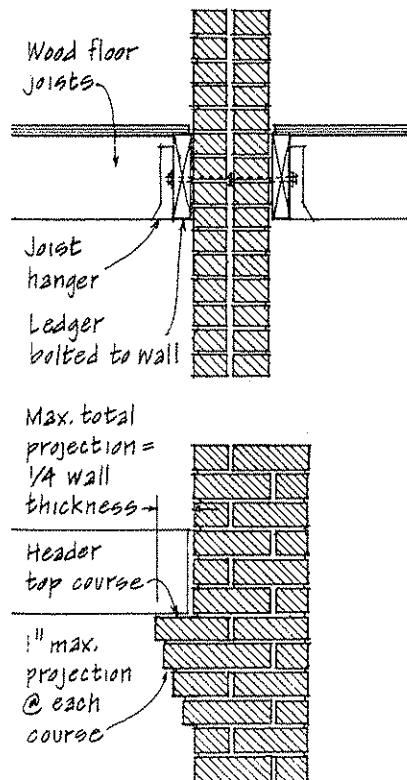
Cement grout

Vertical reinforcement



These wall sections are intended to illustrate how floor and roof systems relate to various types of brick walls. All floors and roofs that provide lateral stability for a masonry wall must be secured to the wall at 4' o.c. with anchors embedded in a reinforced, grouted structural element of the wall.

- For a description of masonry wall types, see 5.20/5.21.
- For floor systems, see Chapter 4.
- For roof systems, see Chapter 6.



Corbel is permitted only in solid walls at least 12" thick.

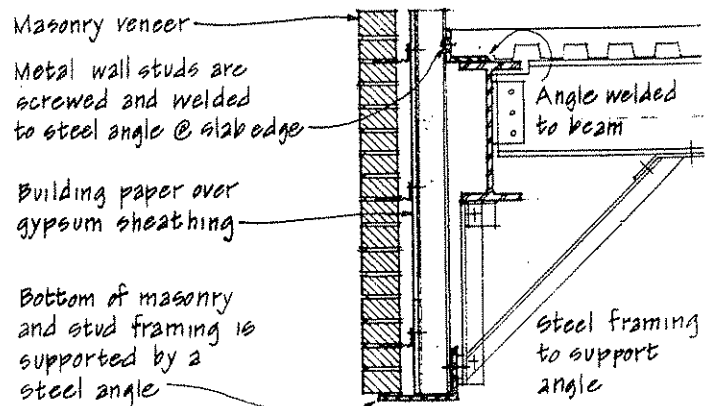
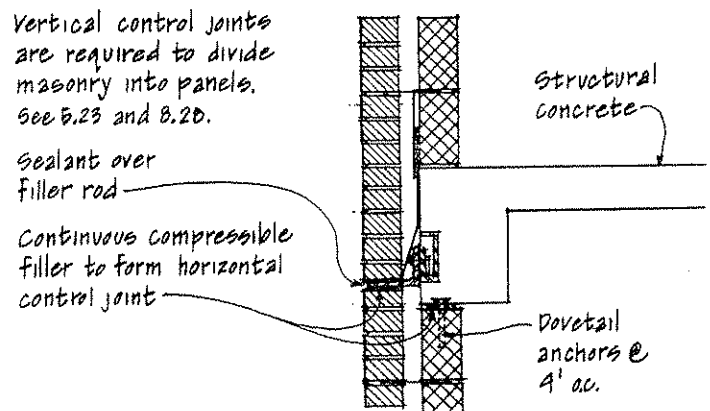
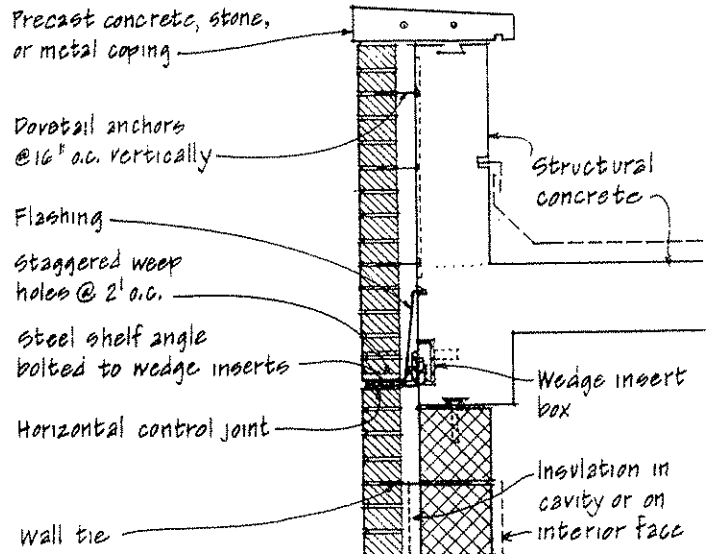
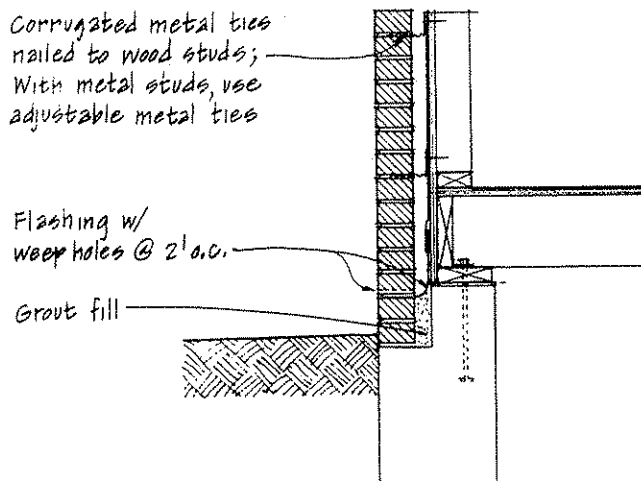
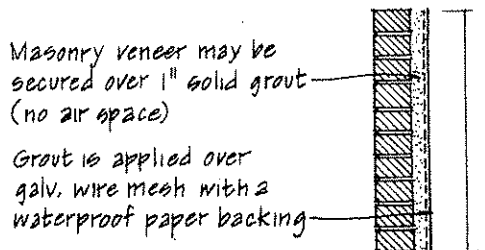
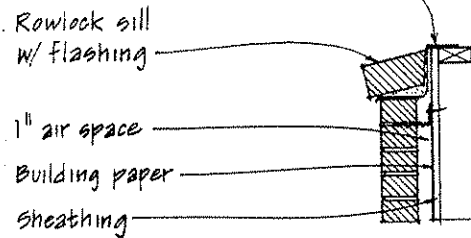
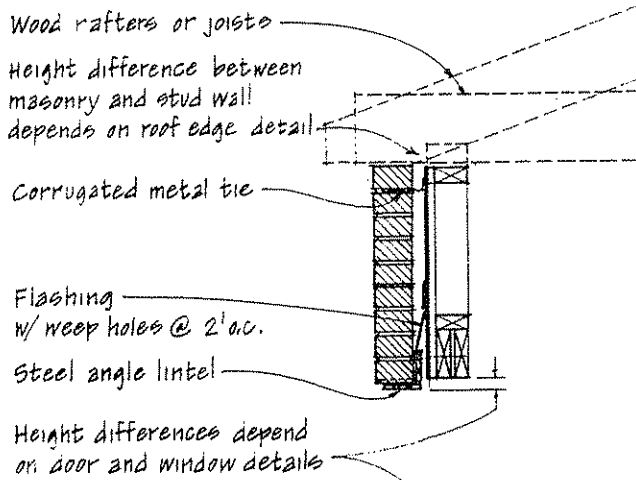
SOLID WALL

REINFORCED MASONRY

REINFORCED MASONRY

5.28

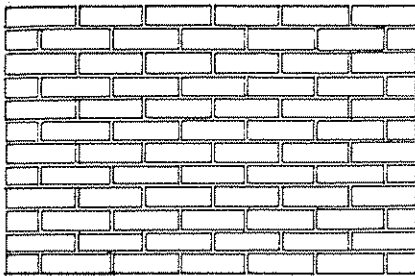
BRICK WALL SECTIONS



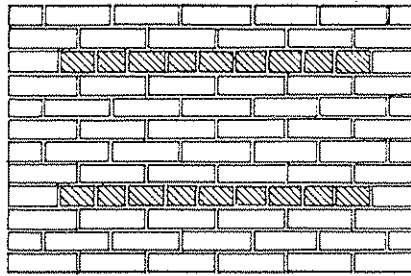
MASONRY VENEER

MASONRY VENEER

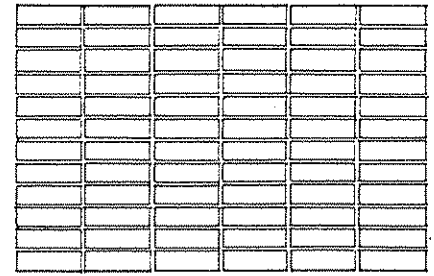
BRICKWORK

Running Bond

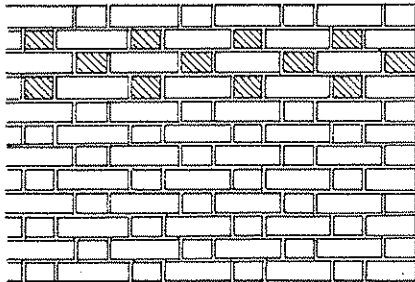
This is the simplest pattern which is used in cavity and veneer walls.

Common Bond

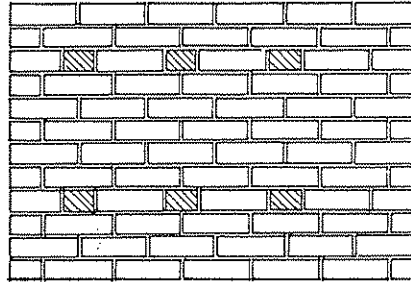
This is similar to running bond except for a header course at every 5th, 6th, or 7th course.

Stack Bond

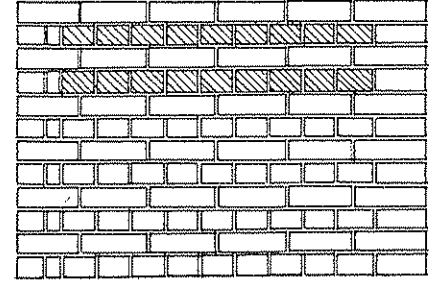
Since units do not overlap, longitudinal reinforcement is required in unreinforced walls @ 16" o.c. vertically.

Flemish Bond

Each course consists of alternating headers and stretchers.

Common Bond

Every sixth course is composed of Flemish headers.

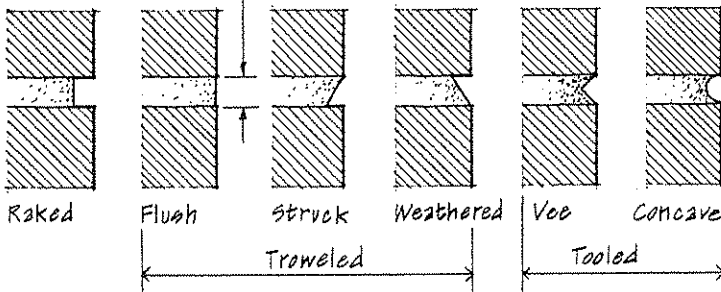
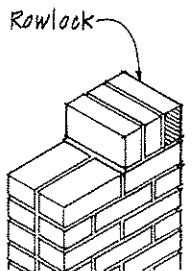
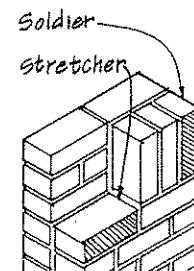
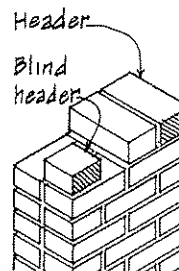
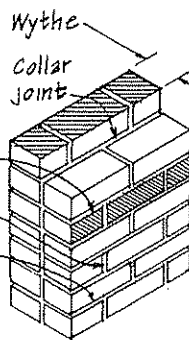
English Bond

Pattern consists of alternating stretcher and header courses.

BRICK BOND PATTERNS

Bed joint are typically $\frac{3}{8}$ " thick. They should not be less than $\frac{1}{4}$ " nor more than $\frac{5}{8}$ " in thickness.

Course
Head joint
Bed joint



Tooling compresses the mortar and forces it tightly against the mortar. Tooled joints provide maximum protection against water penetration and are recommended in areas subject to high winds or heavy rains.

In troweled joints, the mortar is cut or struck off with a trowel. The most effective of these is the weathered joint since it sheds water.

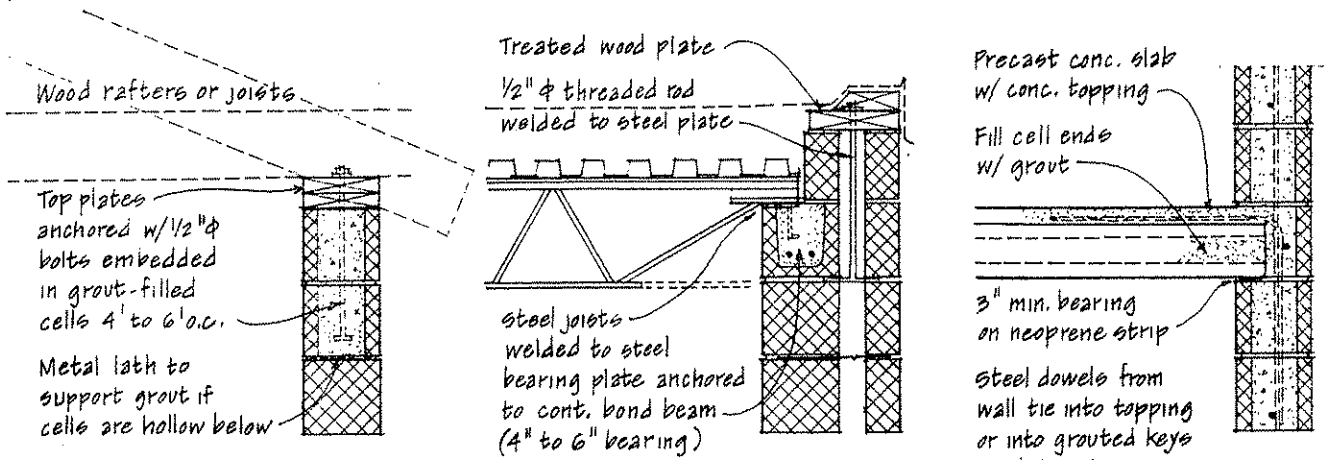
Raked joints are for interior use only.

TYPES OF MORTAR JOINTS

- For mortar types, see 5.10 and 12.6
- For description of brick, see 12.6

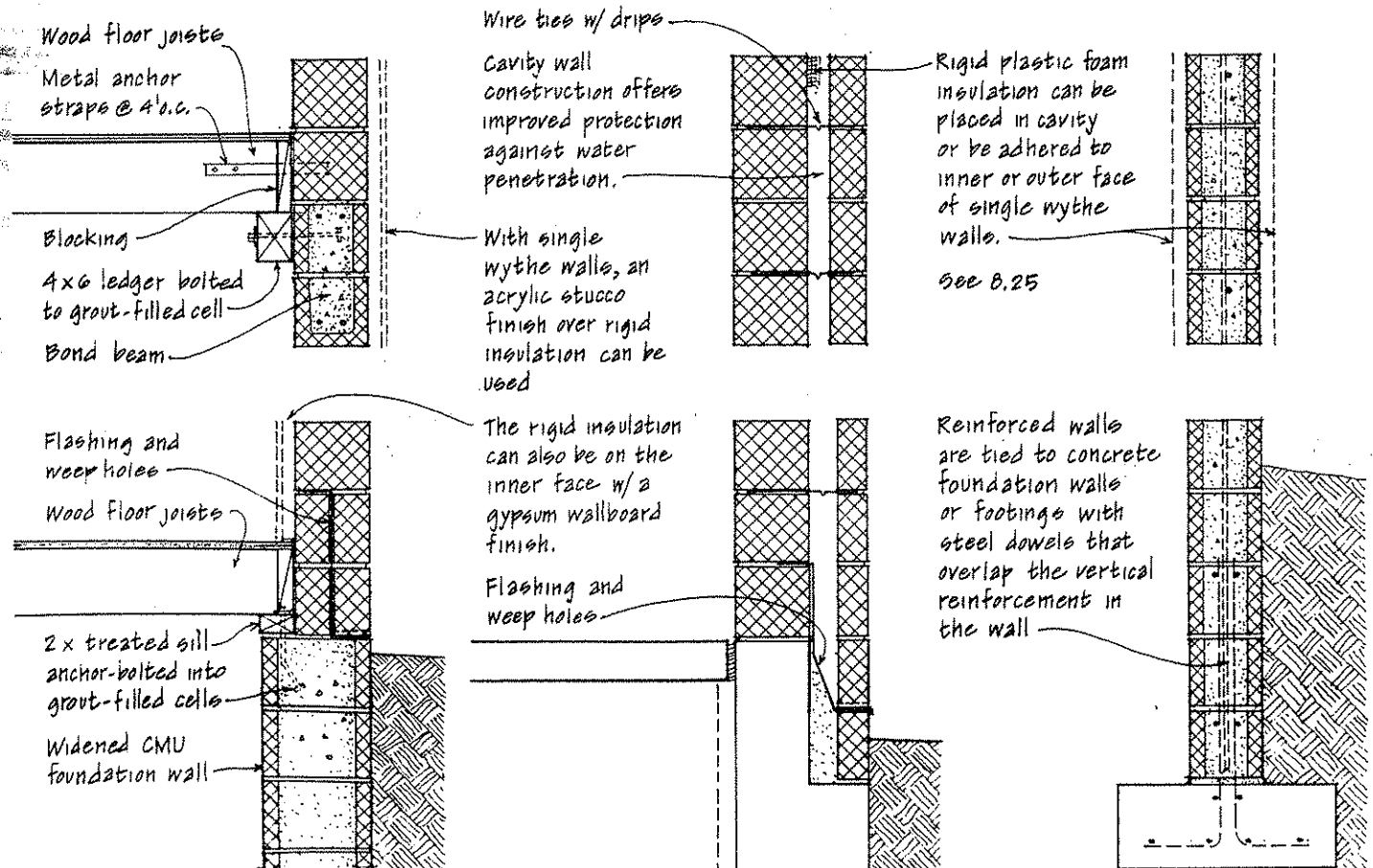
5.50

CONCRETE MASONRY WALL SECTIONS



These wall sections attempt to illustrate how various floor and roof systems relate to concrete masonry unit (CMU) walls. For a description of hollow unit and cavity walls, see 5.20. Bearing area of masonry should be proportioned so that the allowable compressive stresses for the masonry type are not exceeded; see table on 5.19.

- For a description of reinforced hollow unit masonry unit masonry see 5.22.
- For floors, see Chapter 4.
- For roofs, see Chapter 6.

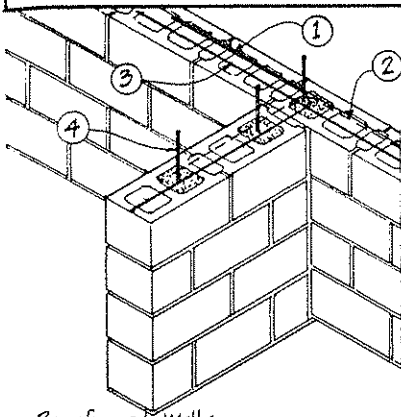


HOLLOW UNIT WALL

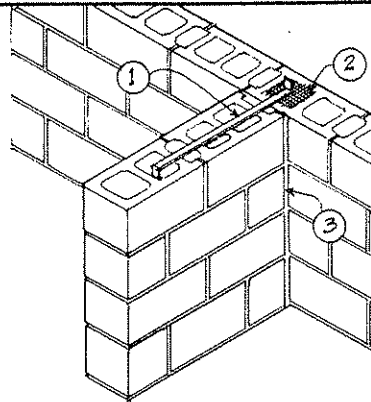
CAVITY WALL

REINF. HOLLOW UNIT WALL

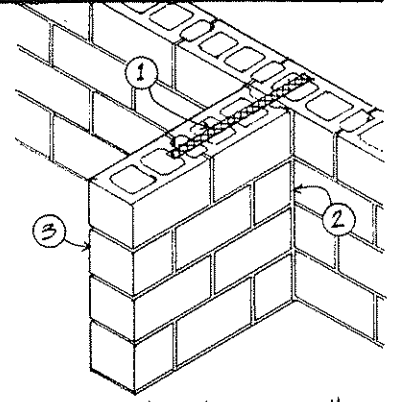
CONCRETE MASONRY

Reinforced Walls

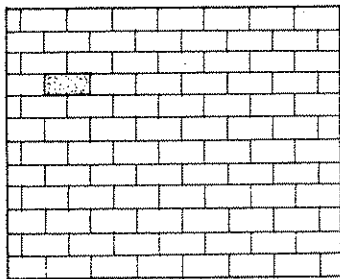
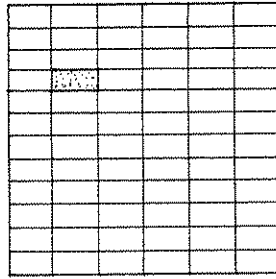
1. Lap splice bars 40 bar diameters or 24"
2. Turn every other bar in opposite direction
3. Horizontal or bond beam reinforcement
4. Vertical reinforcement in fully grouted cells

Unreinforced Bearing Walls

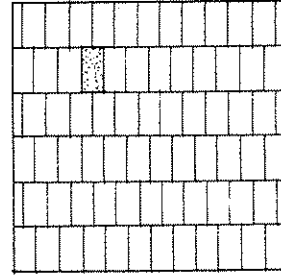
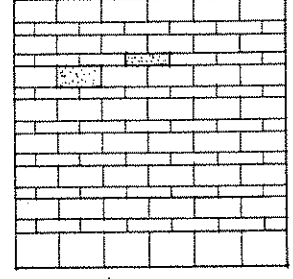
1. 1 1/2" x 1/4" x 30" metal strap anchor w/ends bent up 2"; space vertically @ 4' o.c. maximum
2. Metal lath to support grout in cell above
3. Control joint

Bearing and Nonbearing Wall

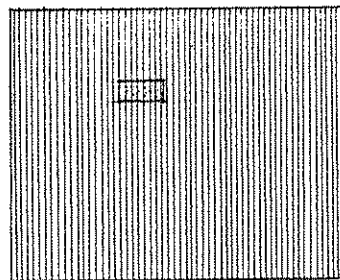
1. Metal lath @ 16" o.c. vertically
2. Control joint - rake and caulk
3. Nonbearing wall

WALL INTERSECTIONSRunning Bond

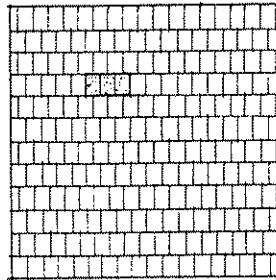
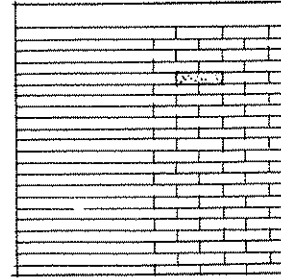
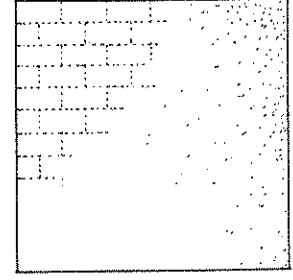
Stack Bond
Requires horizontal joint reinforcement @ 16" o.c. vertically

Running Bond

Coursed Ashlar
Alternating courses of 4" and 8" units



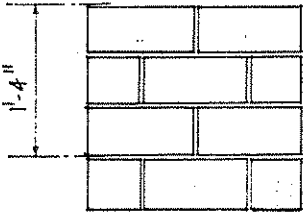
Ribbed Block
With ribbed and grooved block, the color of the mortar should match the color of the block.

Grooved BlockConcrete BrickStucco over blockCONCRETE MASONRY BOND PATTERNS

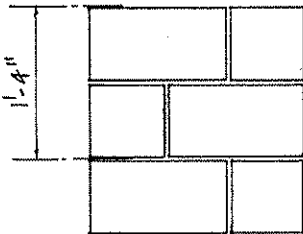
- For mortar joints, see 5.2.9
- For description of concrete masonry units, see 12.7

Structural facing tile is a clay masonry product glazed on one or both faces. These tiles are generally used for interior partitions or the inner wythe of exterior cavity walls, especially when the durable and easily cleaned surfaces of their glazed faces are desired.

There are two shape groups of structural facing tile:



GT shapes have nominal $5\frac{1}{3}$ " x 12" faces

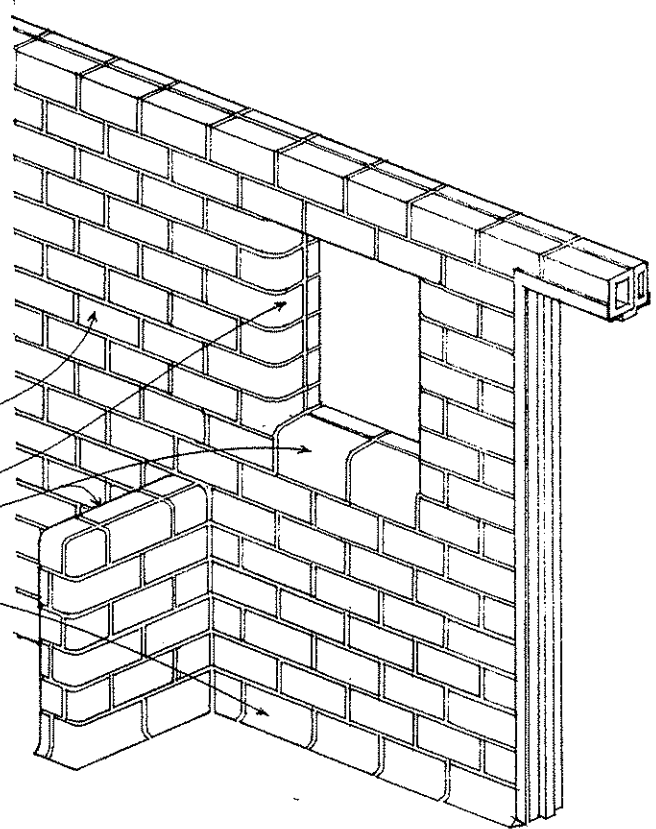


BW shapes have nominal 9" x 16" faces.

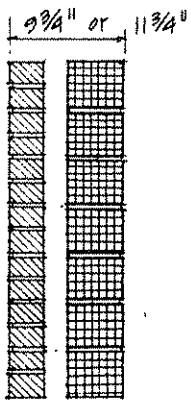
In each shape group, there are several types of units:

- Stretchers
- Corners and jambs
- Sills and caps
- Core bases

Consult manufacturer for specific types, sizes, colors, and nomenclature.



(Nominal dimensions include the thickness of the mortar joints.)



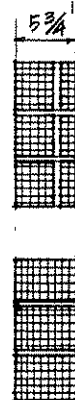
10" or 12" Cavity Wall

- 4" or 6" inner wythe of structural facing tile w/ an outer wythe of brick



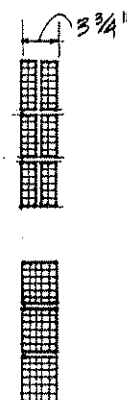
8" Wall

- 2 - 4" wythes w/ metal ties



6" Wall

- A single 6" wythe or
- A 2" and a 4" wythe w/ metal ties; each side may have a different color



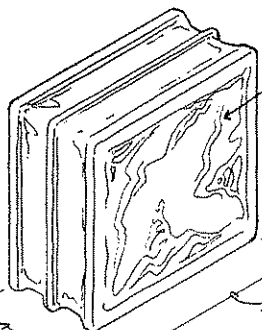
4" Wall

- A single 4" wythe or
- 2 - 2" wythes w/ metal ties

WALL SECTIONS : For hollow unit and cavity wall requirements, see 5.20 and 5.21.

GLASS BLOCK

Glass block may be used in non-loadbearing exterior and interior walls, and in conventionally framed window openings. The glass block units are laid in Type S mortar with joints at least $\frac{1}{4}$ " but not more than $\frac{3}{8}$ " thick. Typically, a wall panel is mortared at the sill support and provided with expansion joints at the head and jamb to allow for movement and settling.



Various surface textures are available as well as inserts and coatings to control heat gain, glare, and brightness.

Square units:
6" x 6"
8" x 8"
12" x 12"

Rectangular units:
4" x 8"
6" x 8"

4" for hollow units
3" for solid units

NOMINAL DIMENSIONS
Includes the thickness of $\frac{1}{4}$ " mortar joints

Exterior wall panels may not exceed 144 S.F. in unsupported wall area nor 15' in any dimension.

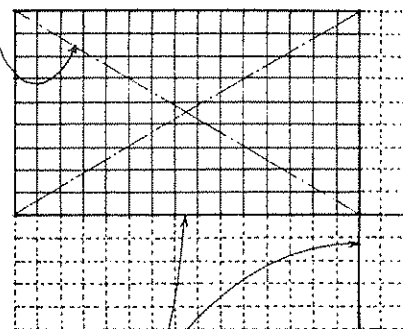
Interior wall panels may not exceed 250 S.F. in unsupported wall area nor 25' in any dimension.

Vertical stiffeners and horizontal shelves can break larger wall areas into the required panel sizes.

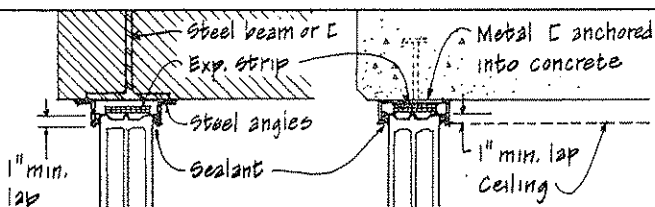
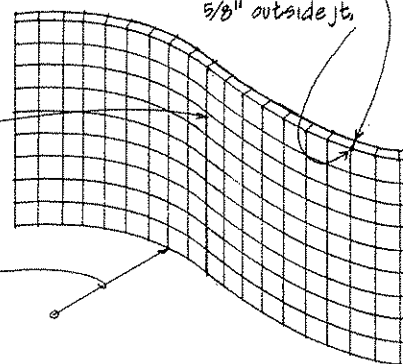
Curved wall panels should have expansion joints at each change of direction.

Minimum radii:

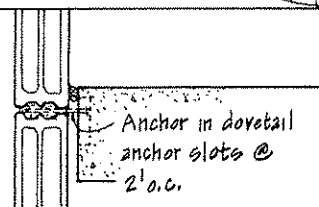
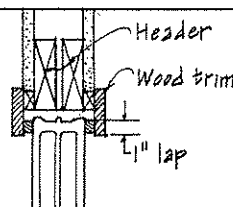
6" glass block - 4'
8" glass block - 6'
12" glass block - 8'



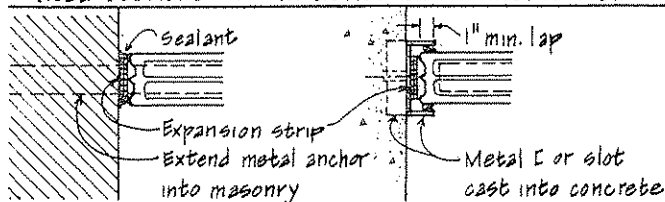
$\frac{3}{16}$ " inside jt.
 $\frac{5}{8}$ " outside jt.



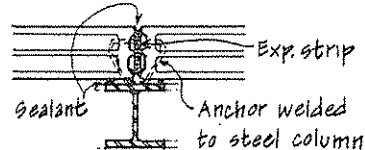
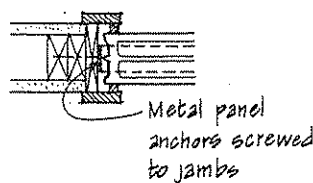
Head Sections: All for deflection of lintel or beam



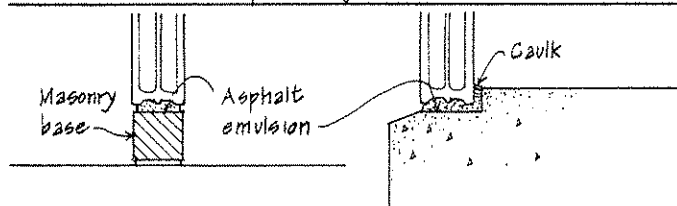
Stiffener @ Slab Edge



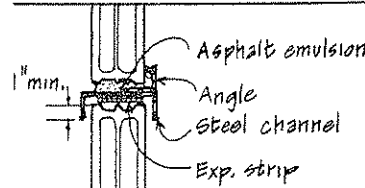
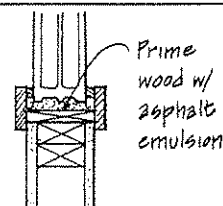
Jamb Sections: Expansion joints



Stiffener @ Column

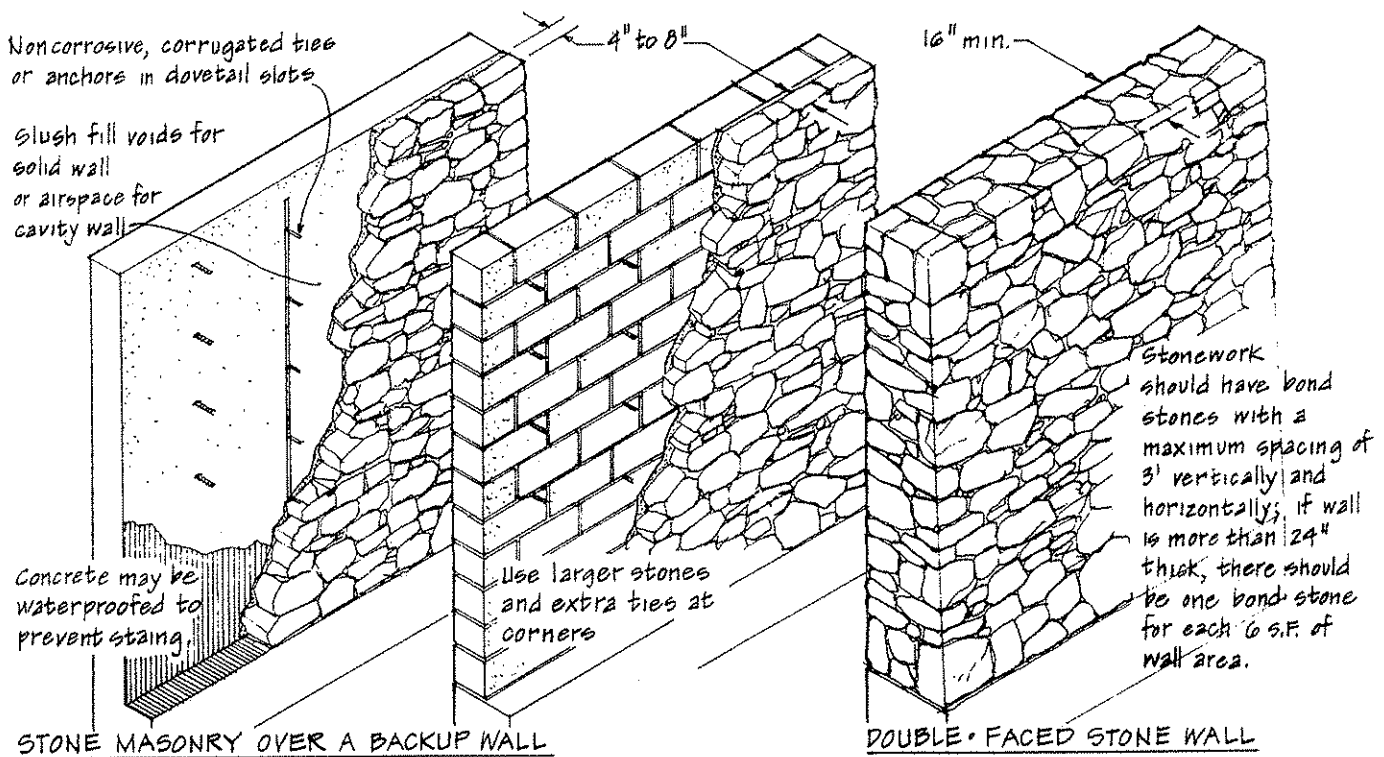


Sill Sections: Mortared joints



Shelf Support

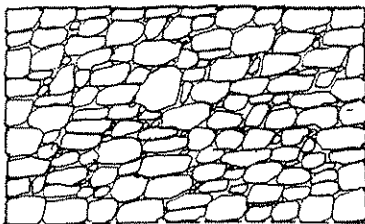
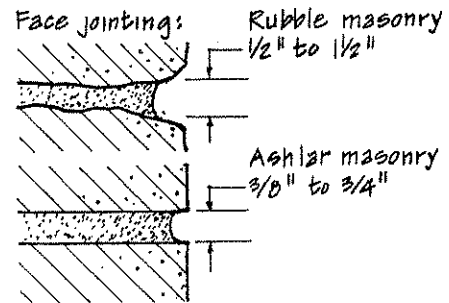
GLASS BLOCK DETAILS



A self-supporting stone wythe is tied to a reinforced concrete or CMU wall.

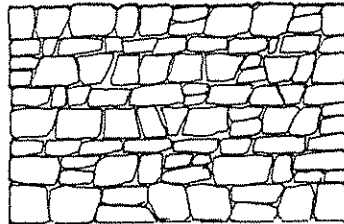
Natural stone may be bonded with mortar and laid up as a double-faced loadbearing wall or used as veneer tied to a concrete or masonry backup wall. The stone should be protected from staining by using nonstaining cement mortar, especially with porous and light colored stones. Only non-corrosive ties, anchors, and flashings should be used. Copper, brass, and bronze may stain under certain conditions.

Stone masonry may be laid up in various patterns as illustrated below.



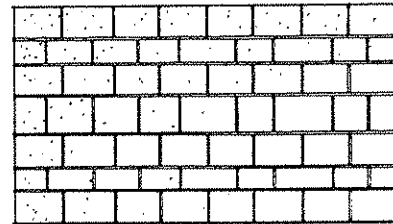
RANDOM RUBBLE

- There is no apparent coursing.
- Bed joints are approximately horizontal for stability and appearance; pointing is kept back of face to emphasize natural shapes of stone.



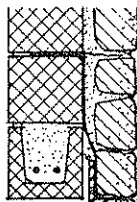
COURSED RUBBLE

- Bed joints are approximately continuous and horizontal.

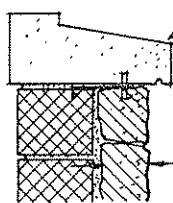


COURSED ASHLAR

- Stone is cut and dressed to design dimensions in the mill.
- Cut stone is laid in a running bond pattern with varying course heights.

Masonry-backed
Stone Wall

steel angle
w/ CMU or
precast conc.
lintel

LINTELSSILLDouble-faced
Rubble Wall

stone or
reinf. concrete
lintel

Stone masonry wall details for:

- foundation supports
- floor and roof system connections
- lateral bracing
- flashing

are similar to those of clay and concrete unit masonry. See 5.26-5.27 and 5.30. Differences will result, however, from the uneven coursing of ashlar masonry, the irregular shapes and sizes of stone rubble, and the varying physical properties of the different types of stone which may be used in a wall's construction. See 12.14.

Wood rafters or roof joists

Treated top plate
set to level in grout
and secured to wall
with $\frac{1}{2}$ " ϕ anchor
bolts

Wood floor joists
3" min. bearing

Anchor straps
@ every 4th joist
(4' o.c. max.) laid
into horizontal joint.

Flat stone for bearing

16" min. thickness

$\frac{1}{2}$ " exp. jt.

Conc. ground slab

Pitch stones to
weather

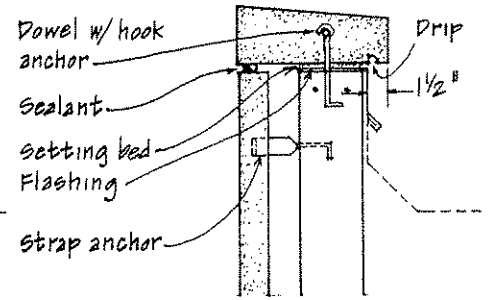
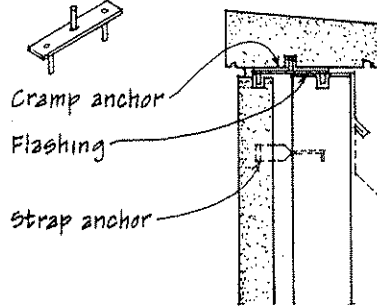
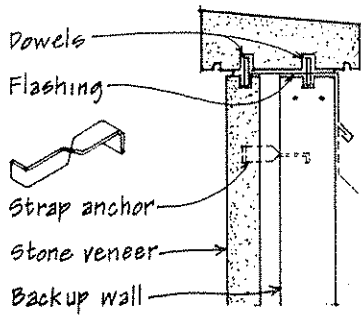
$\frac{1}{2}$ " to $\frac{1}{4}$ " face joints;
keep pointing back
of face

Stone masonry may
rest on a concrete
foundation wall or
continue down to
a concrete footing.

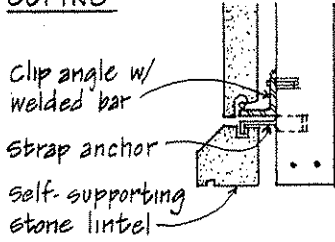
EXAMPLE OF A DOUBLE-FACED RUBBLE WALL SECTION

This type of wall is usually limited to three
stories in height.

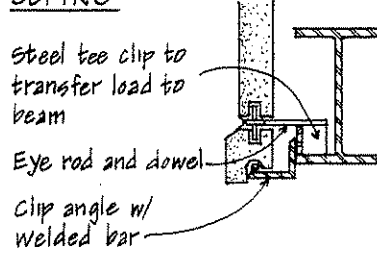
56 STONE VENEER



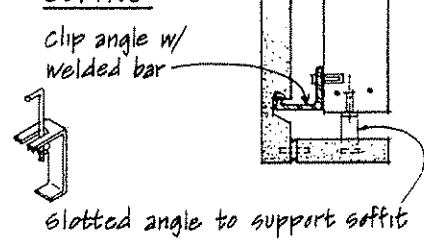
COPING



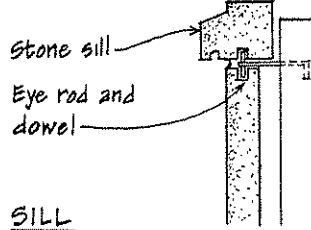
COPING



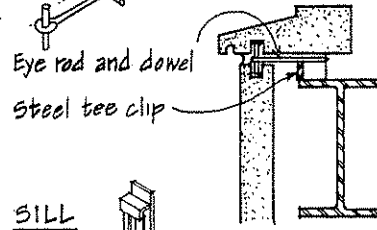
COPING



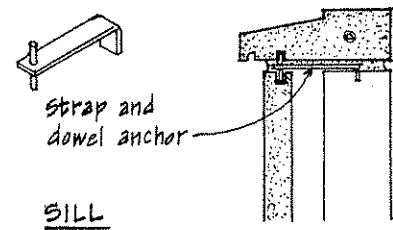
HEAD



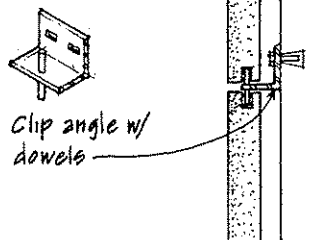
HEAD



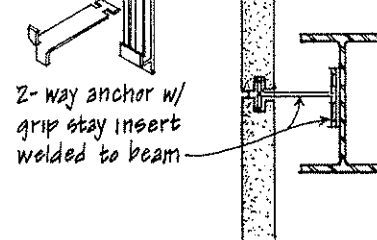
HEAD



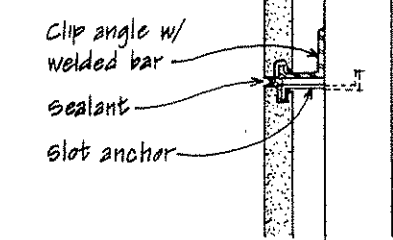
SILL



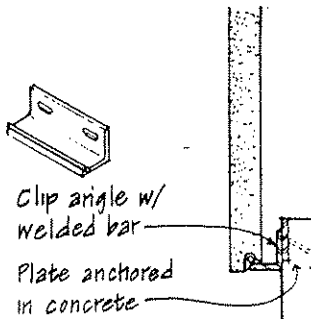
SILL



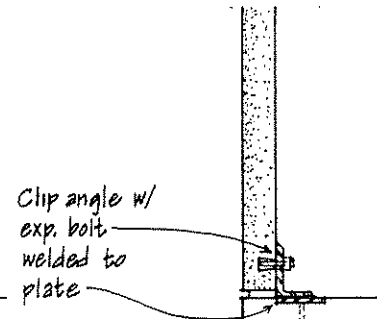
SILL



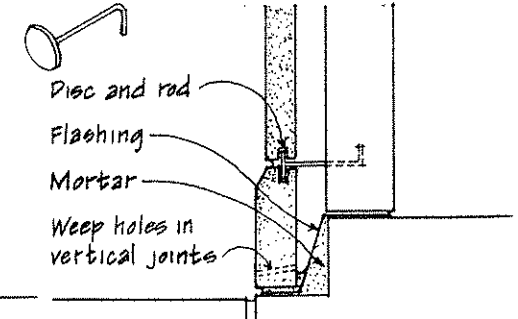
RELIEF ANGLE



SPANDREL BEAM



EXPANSION JOINT



BASE

BASE

BASE

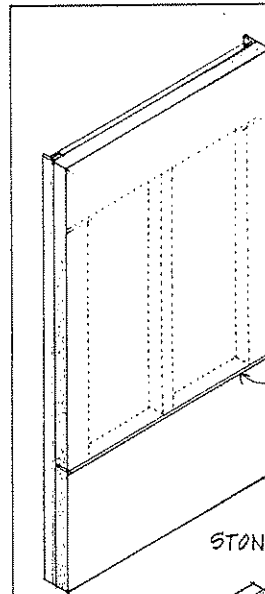
On the facing page are illustrated generalized conditions for fastening stone veneer to a concrete or masonry backup wall or to a structural steel frame. While stone veneer may vary from thin ($1\frac{1}{2}$ "-2 $\frac{1}{2}$ ") panels to thicker (3"-4") facing, the connecting relationships remain similar. The required anchorages should be carefully engineered and take into account the following:

- The stone's strength values
- Gravity and lateral loads
- Expected thermal movement

Some anchors must carry the weight of the stonework and transfer the load to a major structural element. Others only restrain the stonework from lateral movement. Still others must offer shear resistance.

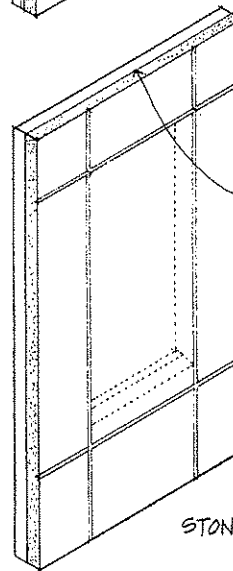
All connecting hardware should be of stainless steel to resist corrosion and prevent staining of the stonework. Adequate tolerances must be built in to allow for proper fitting and shimming, if necessary.

For accurate assembly and economy in on-site labor costs, stone veneer may be preassembled into panels in the shop. The stone units may be attached to a steel frame or to a precast concrete panel.



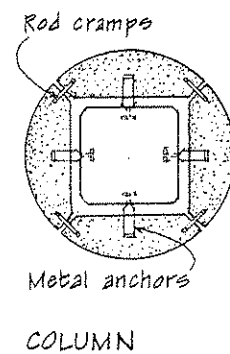
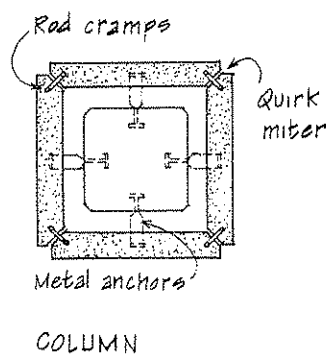
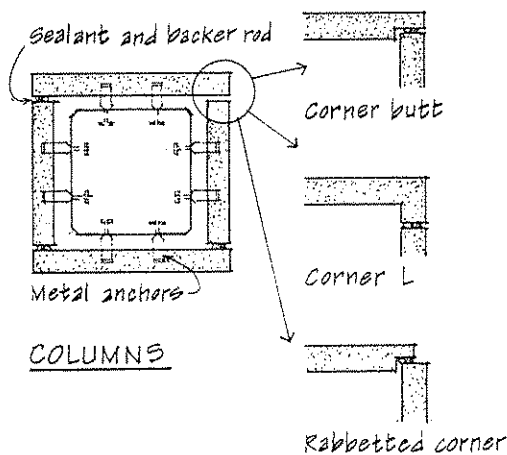
STONE PANEL ON STEEL FRAME

- Stone units are shimmed and anchored to a steel frame with standard connecting hardware and expansion bolts.
- The steel frame, in turn, is designed to be supported by and anchored to the structural frame of the building.
- Joints may be epoxied in the shop or sealed on site.
- Window units are feasible.



STONE PANEL ON PRECAST CONCRETE

- Stone units are secured to a reinforced precast concrete panel with bent stainless steel anchors.
- A moisture barrier and bonding agent is applied between the concrete and stone to prevent concrete salts from staining stonework.
- Window units are feasible.



5.58 STEEL COLUMNS

Cruciform
(4 L's)

Round pipe

Welded plates

Welded plates

Rectangular
or square
tubing

W shape

Double
wood beam

Steel connector
welded to column

BEAM CONNECTIONS

For steel beam
connections,
see 4.22.

The most frequently used section for columns is the wide-flange (W) shape. It is suitable for connections to beams in two directions and all of its surfaces are accessible for making bolted or welded connections. Other steel shapes used for columns are round pipes and square or rectangular tubing. Column sections may also be fabricated from a number of shapes or plates to fit the desired end use of a column.

Steel columns may be left exposed if this is consistent with the required fire-resistance rating for the structure's size and use. For fireproofing of steel structures, see A.12.

As a column's load diminishes, different flange thicknesses may be used at a column-to-column connection.

A filler plate can make up the difference in flange thicknesses at a bolted connection.

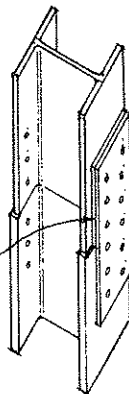
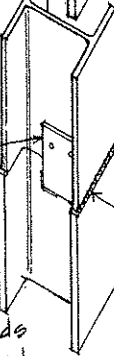
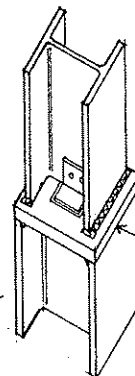


Plate to keep col-
umns
aligned
until welds
are formed



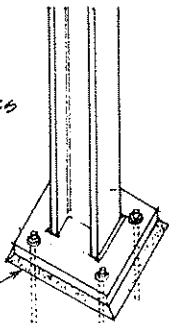
Welded
butt con-
nection



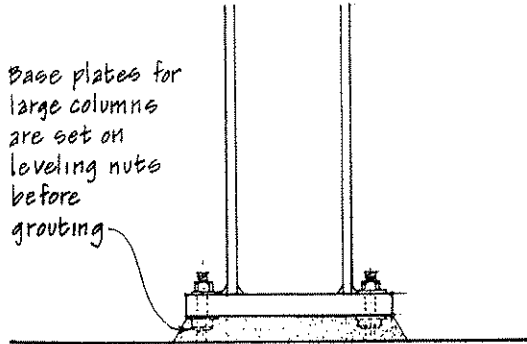
When a change in a column's nominal size occurs, a thick butt plate (welded to both column sections) is used to transfer the load.

COLUMN SPLICES

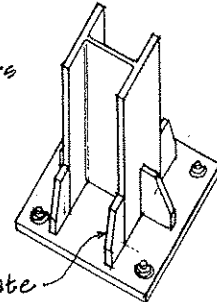
Column is
welded to its
steel base
plate after
the plate is
leveled on
a bed of
grout.



Base plates for
large columns
are set on
leveling nuts
before
grouting.



Stiffeners
may be
required
when a
column
bears on
a thin
base plate.



COLUMN BASES





A steel base plate is required to distribute a column's concentrated load to the concrete foundation to ensure that the allowable stresses in the concrete are not exceeded.

STEEL COLUMN LOAD TABLE

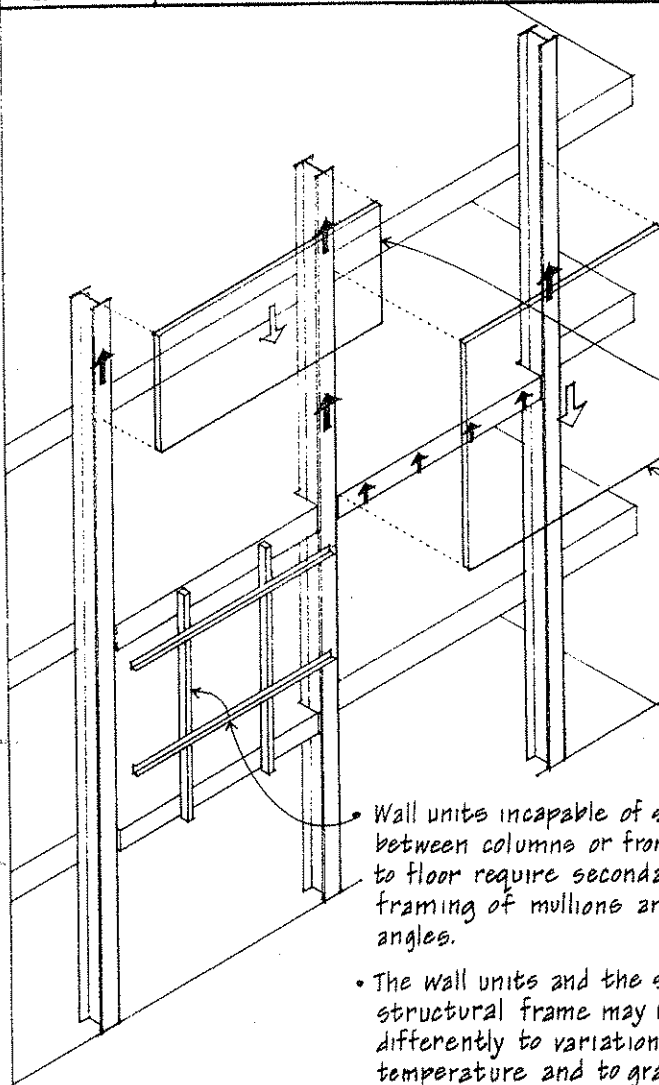
D.59

The allowable load on a steel column depends on its cross-sectional area and its slenderness ratio (L/r), where (L) is the unsupported length of the column in inches and (r) is the least radius of gyration for the column's cross section. The table below should be used for preliminary sizing only.

ALLOWABLE CONCENTRIC LOADS ON COLUMNS IN KIPS. 1 Kip = 1000 lbs.

Round Pipes and Rectangular Tubing	Wall thickness (in.)	Unsupported length in feet								
		8	10	12	14	16	18	20	22	24
 3" (3 1/2" OD)	0.216	34	28	22	16	12	10			
	0.300	45	37	28	21	16	12			
	0.600	77	60	43	32	24				
	3 1/2" (4" OD)	0.226	44	38	32	25	19	15	12	10
	0.318	59	51	43	33	25	20	16		
4" (4 1/2" OD)	0.237	54	49	43	36	29	23	19	15	13
	0.337	75	67	59	49	39	31	25	21	17
	0.674	133	118	100	81	62	49	40	33	
5" (5 3/16" OD)	0.250	78	73	68	61	55	47	39	32	27
	0.375	111	103	95	86	76	65	54	44	37
	0.750	202	187	170	151	130	108	87	72	61
6" (6 3/8" OD)	0.280	106	111	105	99	82	75	67	59	51
	0.432	159	151	142	132	122	111	99	86	73
	0.864	292	275	257	237	216	193	168	142	119
 	3" x 3"	0.250	44	32	23	17				
	4" x 4"	0.250	73	64	54	42				
	5" x 5"	0.250	103	95	86	76	65	53		
	6" x 6"	0.250	132	124	116	107	98	87	76	64
	2" x 4"	0.250	25	16	11					
	3" x 4"	0.250	54	42	29	22	17	13		
	3" x 6"	0.250	74	59	43					
	4" x 6"	0.250	96	86	74	60				
	4" x 8"	0.250	119	107	93	78	61			
W- Shapes		Wt. (lbs.) per foot								
	W4	13	51	39	27	20	15			
	W5	16	74	64	52	39	30	24	19	
	W6	15	75	67	58	48	38	30	24	17
		20	100	91	80	68	54	43	35	24
W8		25	126	114	101	86	70	55	45	31
		24	123	113	101	88	73	59	47	33
		28	144	132	118	103	86	69	56	39
		31	169	159	148	136	123	110	95	66
		35	191	180	168	155	141	125	109	76

VP D.40 STEEL FRAME WALLS

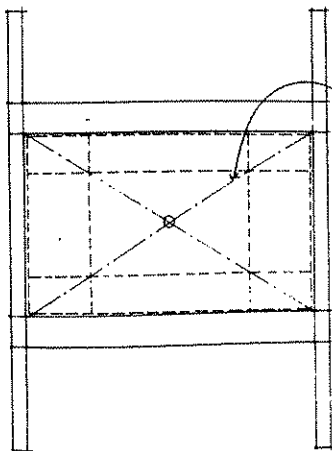


Wall units incapable of spanning between columns or from floor to floor require secondary framing of mullions and shelf angles.

- The wall units and the supporting structural frame may respond differently to variations in temperature and to gravity or wind loads. Connection details should allow for the differential movement between the wall and structural frame, as well as between the wall units themselves.

- The wall may be subject to both wind pressure and suction.

If diagonals are used to brace the structural frame, they will affect the design of the wall units.

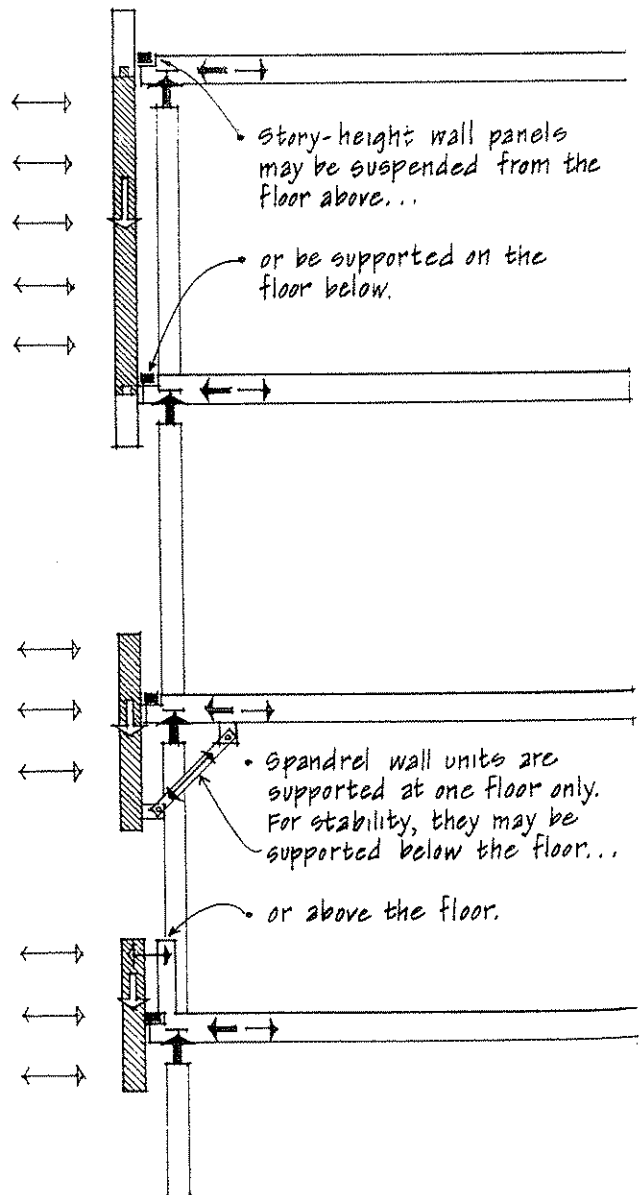


Since the columns in a steel frame structure carry the loads, the exterior walls are non-load bearing. They can therefore be relatively thin, lightweight claddings of:

- Metal and glass (7.28)
- Precast concrete (5.48)
- Masonry (5.28)
- Cut stone (5.36)

These walls may be supported by:

- The columns alone
- The columns as well as by spandrel beams or the edges of floor slabs

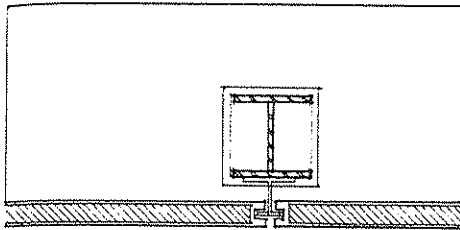


Story-height wall panels may be suspended from the floor above...

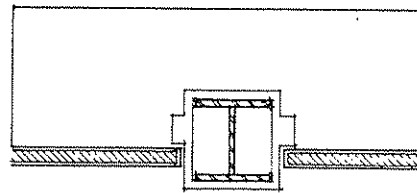
...or be supported on the floor below.

Spandrel wall units are supported at one floor only. For stability, they may be supported below the floor...

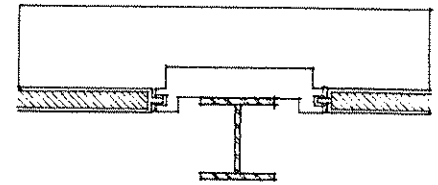
...or above the floor.



Column behind the wall



Column in the wall plane



Column in front of the wall

These diagrams illustrate the three basic column-wall relationships. The specific detail in each case must incorporate, in addition to the structural support of the wall panels, the following:

- protection against moisture
- protection against air movements
- thermal and sound insulation
- the required degree of fire resistance

To allow for discrepancies between the dimensions of the wall units and the structural frame, the anchoring devices should permit adjustment in three dimensions. Shims and slotted holes are usually used for this purpose.

After the final adjustments are made, the connections can be permanently secured by welding.

ANCHORING DEVICES

- structural tees or brackets bolted or welded to column flange

- Angle clip shimmed and bolted or welded to flange of spandrel beam

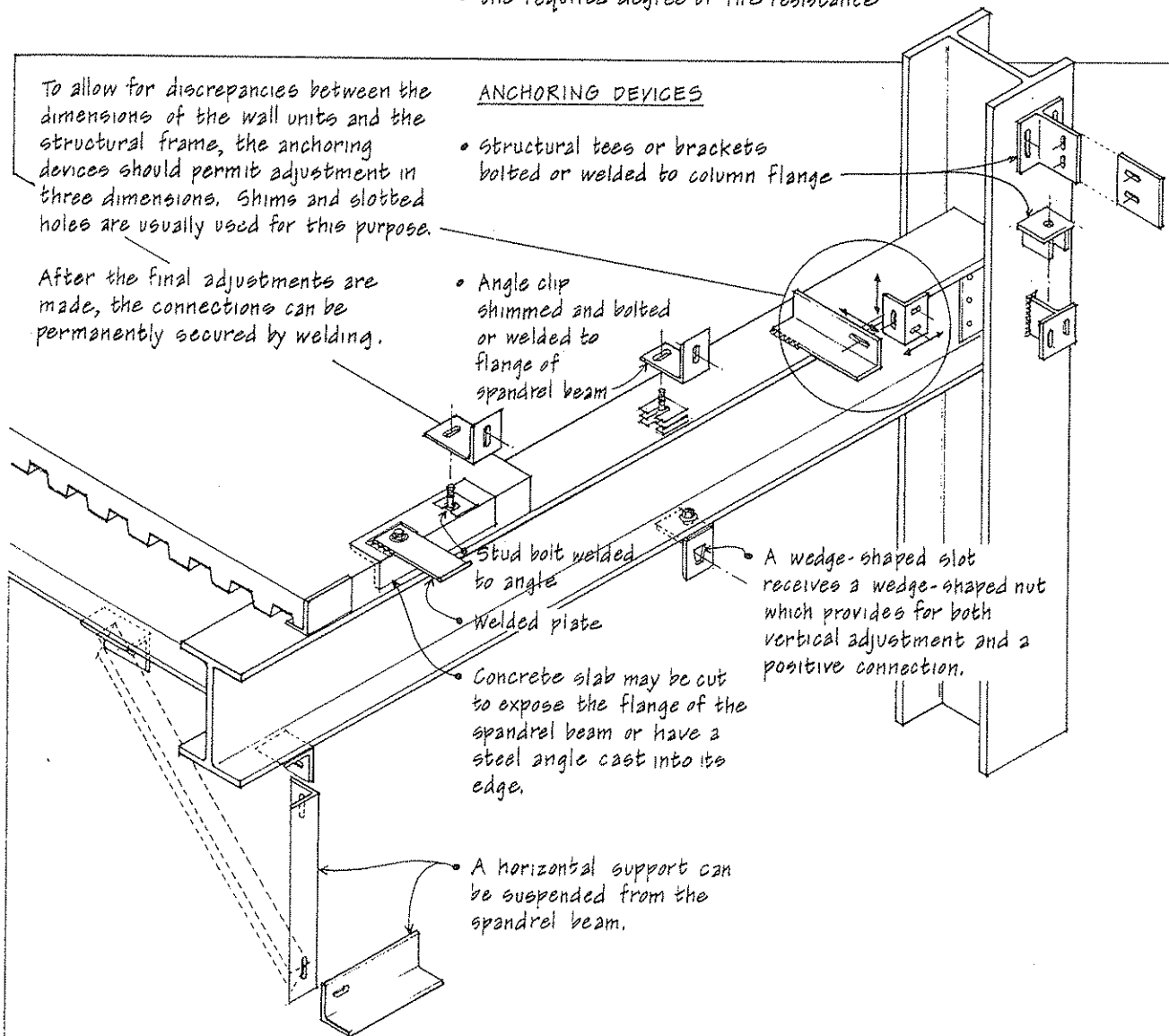
- Stud bolt welded to angle

- Welded plate

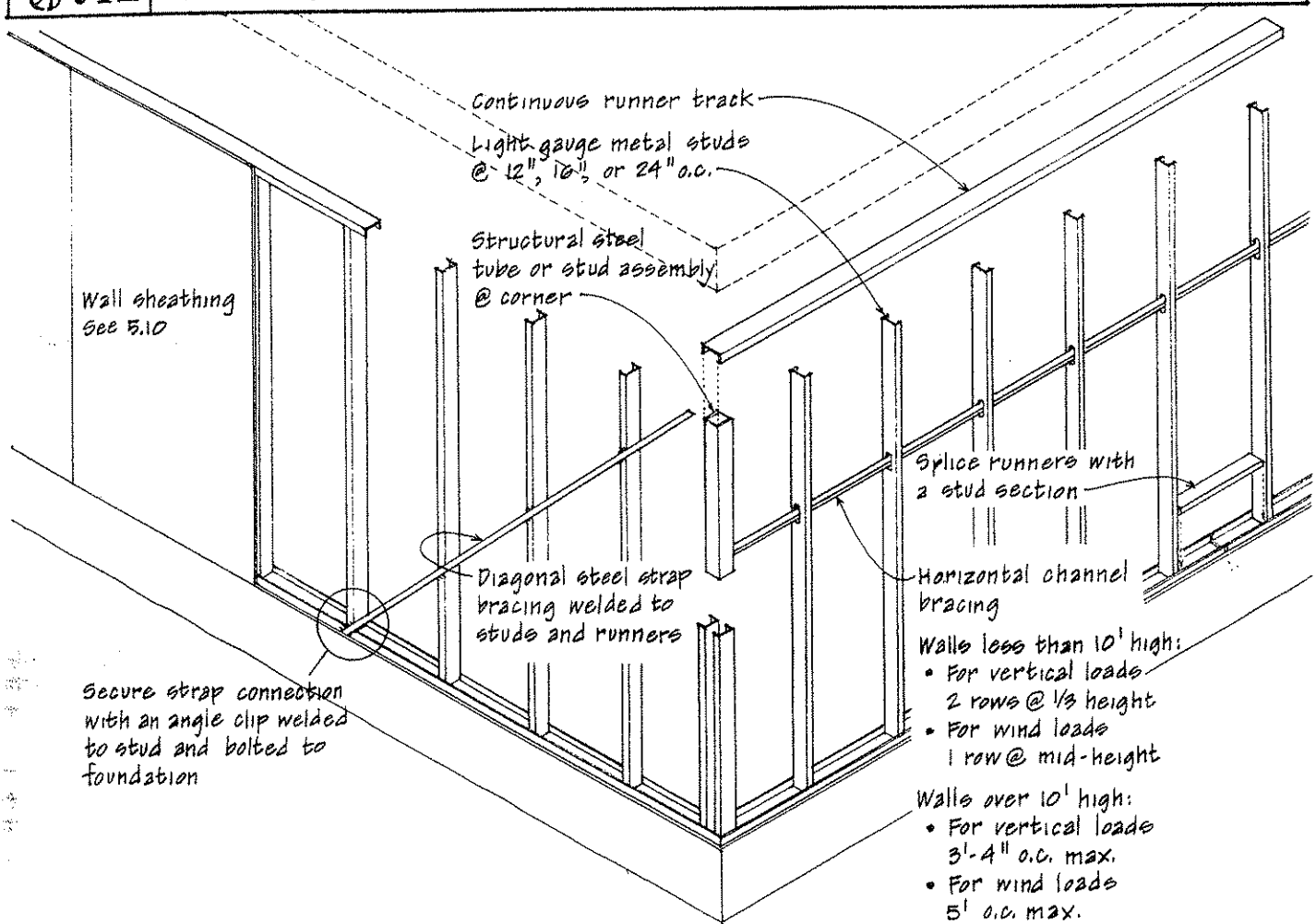
- Concrete slab may be cut to expose the flange of the spandrel beam or have a steel angle cast into its edge.

- A horizontal support can be suspended from the spandrel beam.

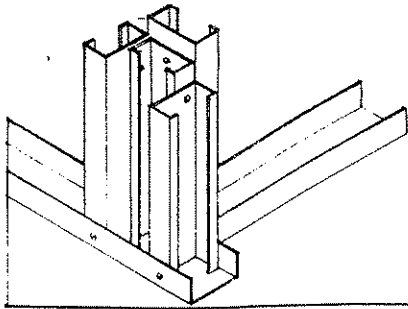
- A wedge-shaped slot receives a wedge-shaped nut which provides for both vertical adjustment and a positive connection.



5.42 LIGHT GAUGE STEEL WALL FRAMING



Light gauge steel stud framing systems are similar in form and layout to wood stud wall systems and accept the same range of finishes. See 5.11. They may be used as non-loadbearing partitions or as bearing walls supporting light gauge steel joists.

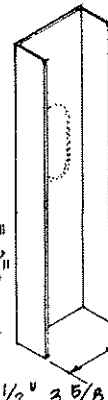


Connections may be made with screws or welds.

C-stud



Channel Stud



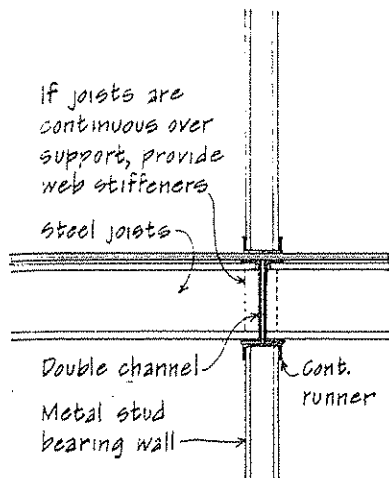
studs may be punched or unpunched. Consult manufacturer for specific shapes and available sizes and gauges.

Dimensions for C-stud: $\frac{1}{4}$ ", $\frac{3}{8}$ ", $\frac{1}{2}$ ", $\frac{5}{8}$ "

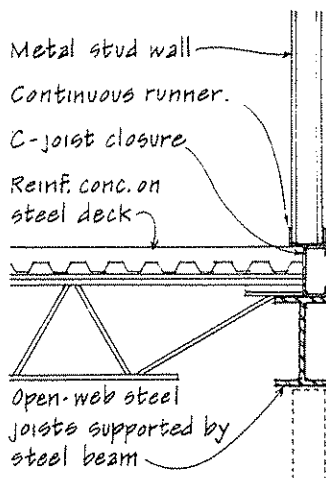
Dimensions for Channel Stud: $\frac{1}{4}$ ", $\frac{3}{8}$ "

Other dimensions: $2\frac{1}{2}$ ", 3", $3\frac{1}{2}$ ", $3\frac{5}{8}$ ", 4", $5\frac{1}{2}$ ", 6", $7\frac{1}{2}$ ", 8"

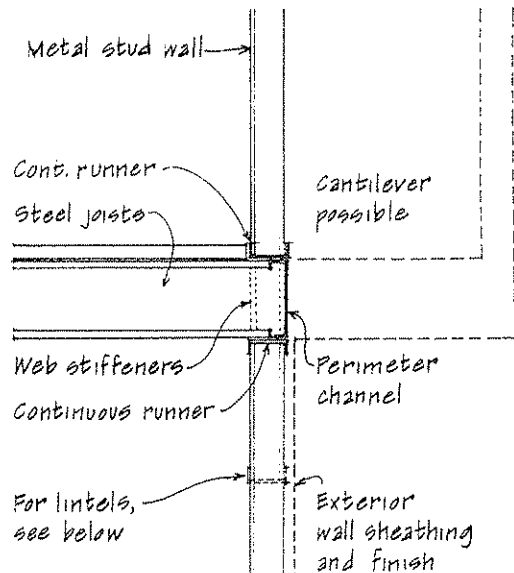
LIGHT GAUGE STEEL STUDS (14 through 22 g2.)



INTERIOR PARTITION



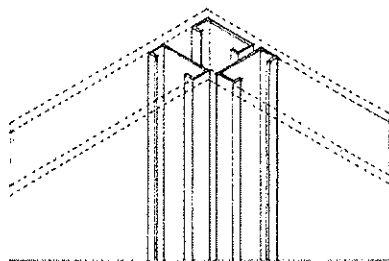
EXTERIOR WALL



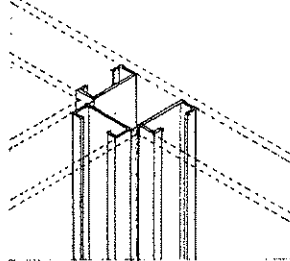
For lintels, see below

Exterior wall sheathing and finish

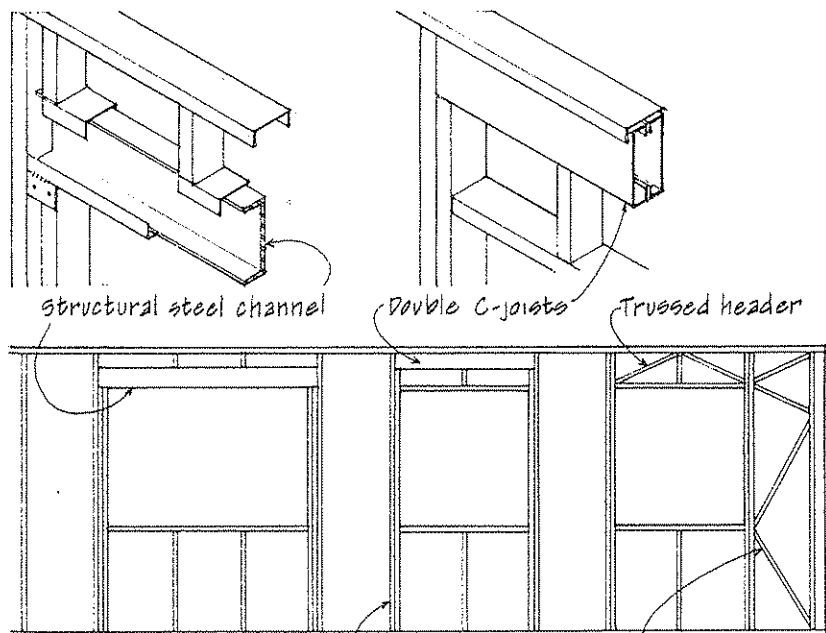
Horizontal channel bracing



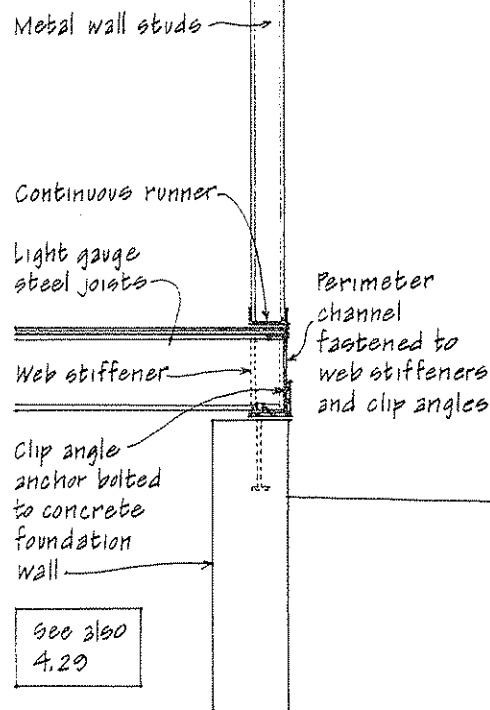
STUD ASSEMBLY @ CORNER



@ PARTITION INTERSECTION



FRAMING OF OPENINGS



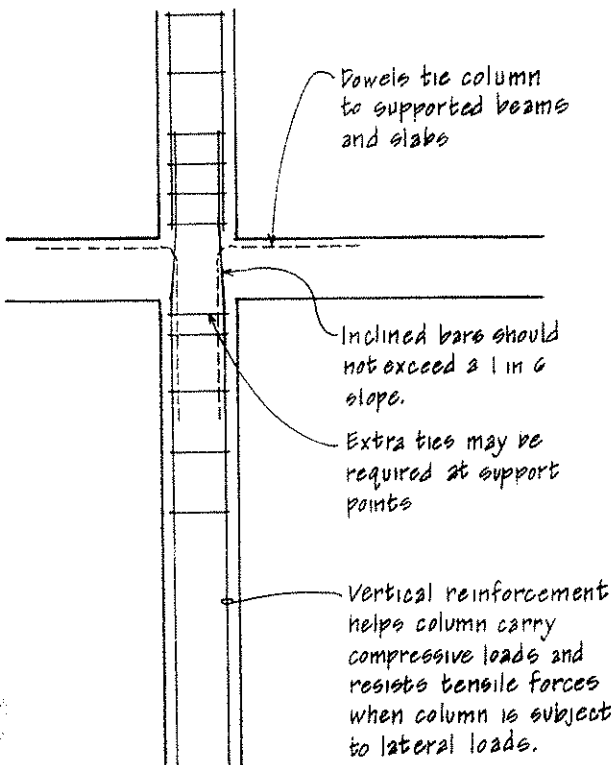
See also 4.29

EXTERIOR WALL SECTION

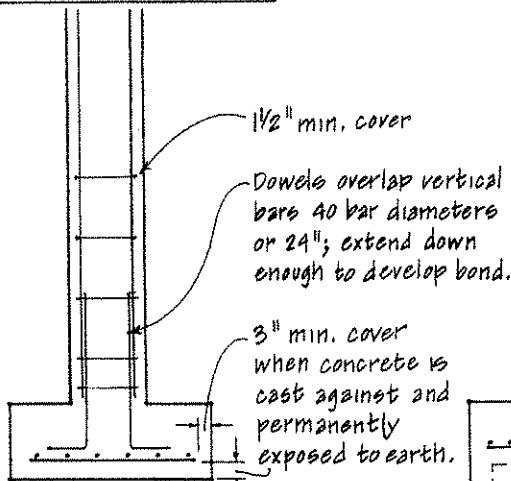
Trussed bridging at corners next to openings

4.4.4

REINFORCED CONCRETE COLUMNS



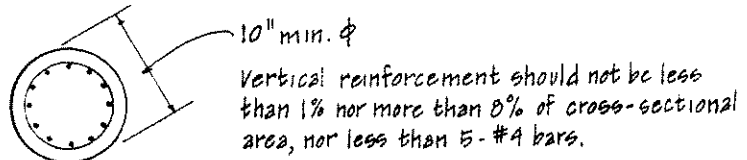
VERTICAL REINFORCEMENT



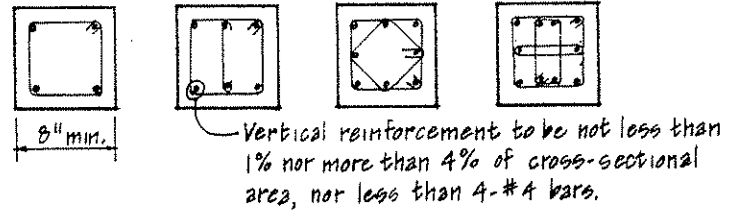
Base area of footing distributes column load to ensure that bearing capacity of supporting soil is not exceeded.

ISOLATED FOOTINGS

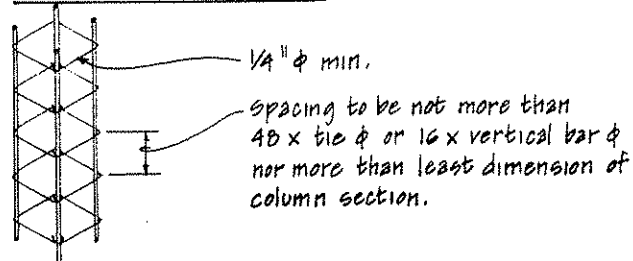
Concrete columns may be supported by isolated footings, a mat or combined footing, or by pile cap.



ROUND COLUMNS

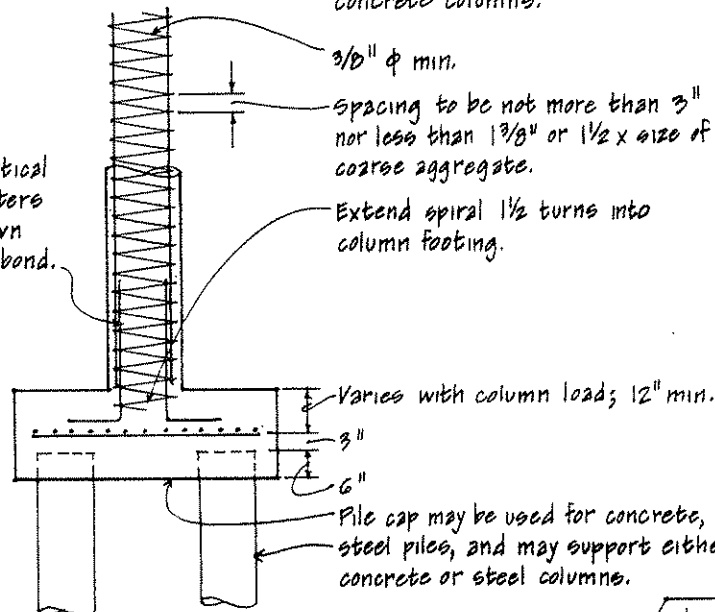


RECTANGULAR COLUMNS

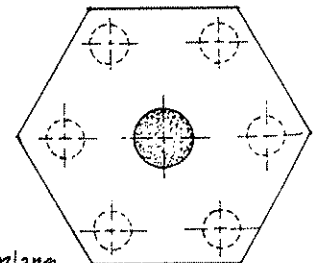
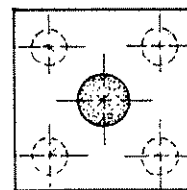
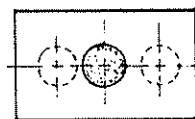


COLUMN TIES

Ties provide lateral reinforcement for concrete columns.



PILE CAPS



Examples of pile cap plane

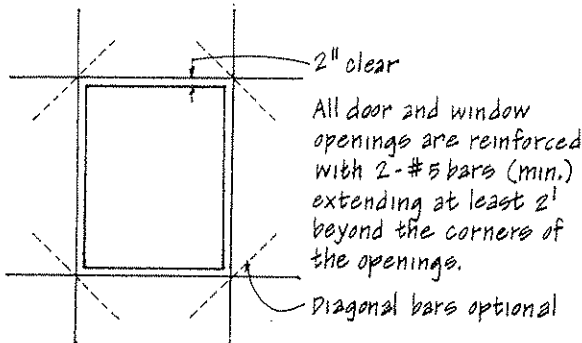
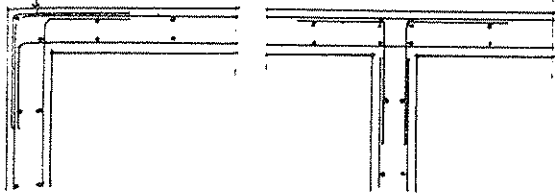
Pile cap may be used for concrete, wood, or steel piles, and may support either concrete or steel columns.

REINFORCED CONCRETE WALLS

D.4.5

Concrete walls should be anchored to floors, or to columns, pilasters, or intersecting walls with #3 bars (min.) @ 12" o.c. for each layer of wall reinforcement.

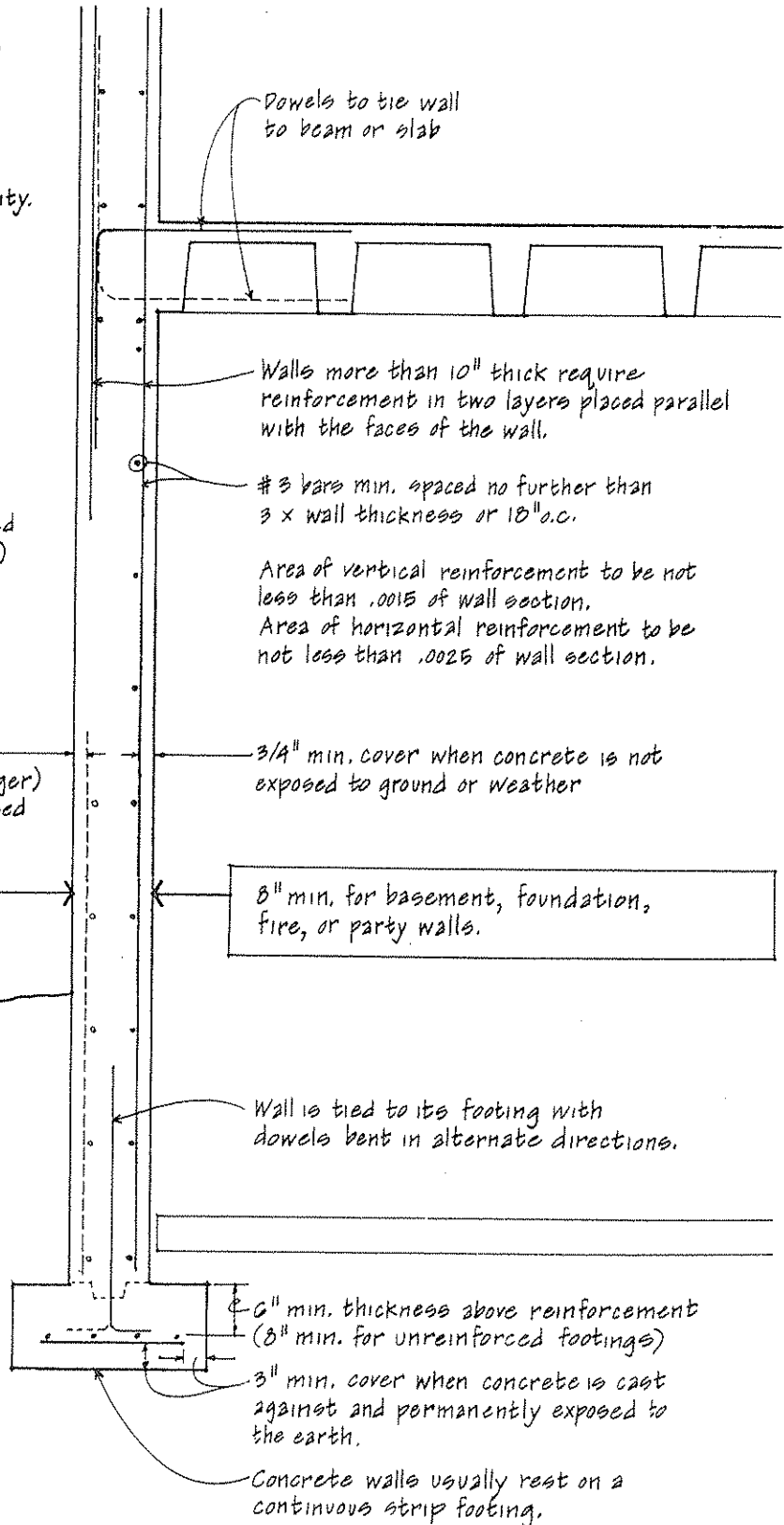
Horizontal reinforcement is bent at corners and wall intersections for structural continuity.



1 1/2" min. cover
(2" for #6 bars and larger)
when concrete is exposed
to earth or weather

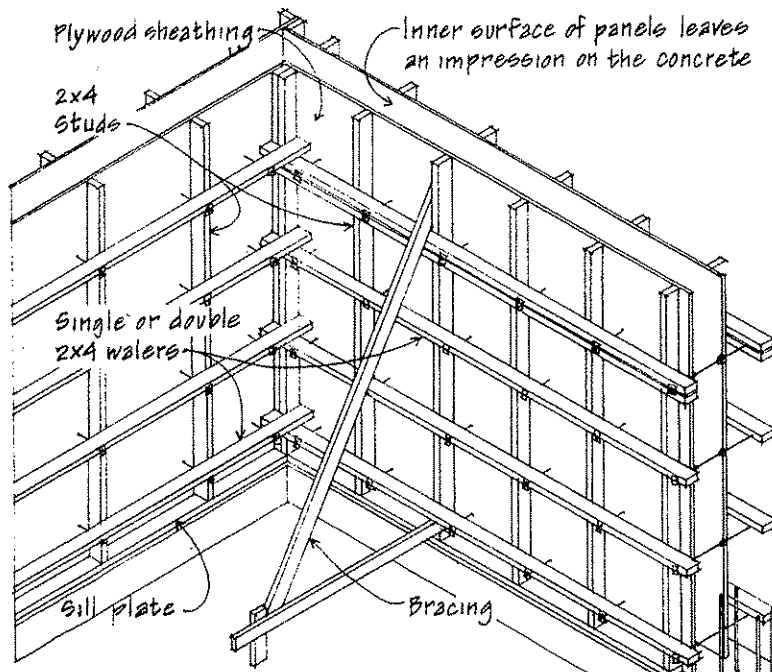
- 6" min. thickness for bearing walls or 1/25 of the unsupported distance between horizontal or vertical stiffening elements.
- 4" min. thickness for nonbearing walls or 1/36 of unsupported distance.
- 2" min. thickness for nonbearing interior partitions not used as shear elements.
- 6" min. thickness for plain (unreinforced) walls with a height-to-thickness ratio of less than 22.

* The size, spacing, and placement of reinforcement should be determined by calculation by a qualified structural engineer.



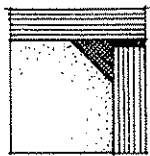
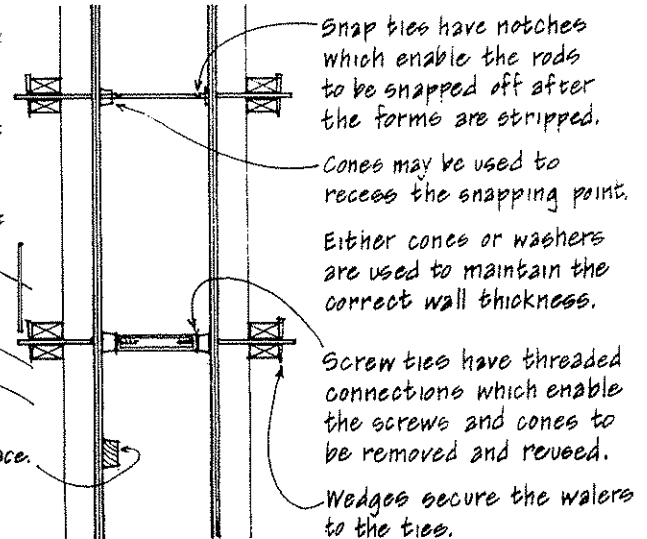
D.46

CONCRETE WALLS: FORMWORK

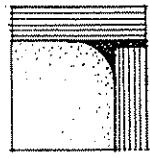


Concrete formwork may be custom-built for a specific job, but prefabricated, reusable panels are used whenever possible. The framework and bracing must be able to maintain the position and shape of the forms until the concrete sets.

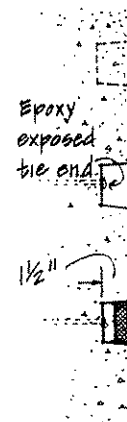
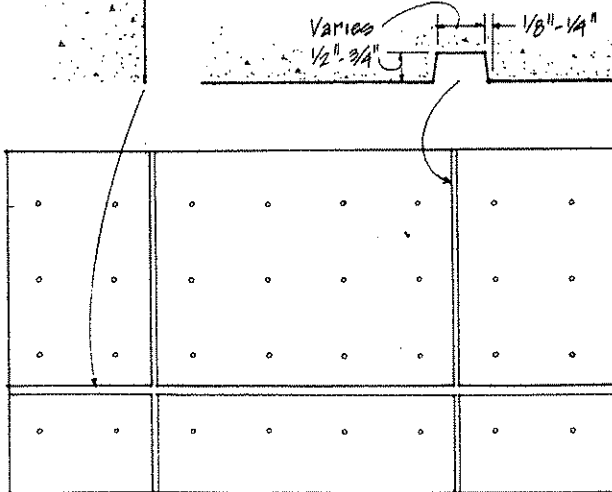
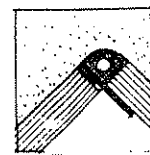
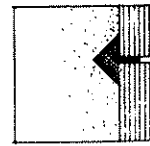
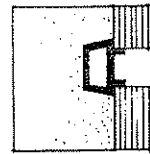
Ties are required to hold the formwork together under the pressure of the wet concrete. While various proprietary forms are available, there are two basic types.



Wood rustication strips are used to form recesses in the wall surface. These strips are also available as parts of plastic formliner systems.



Linear recesses can be used to articulate a wall's surface pattern, separate different wall surface treatments, and to help conceal construction joints.



Tie holes may be:

- patched to match the surrounding
- left exposed
- filled with a plastic cap.

When exposed or visible, the tie hole locations should be coordinated with the wall's surface design.

CONCRETE WALLS: SURFACES

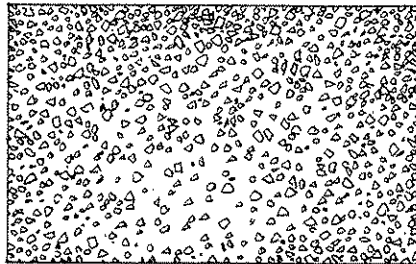
Vº 47

Various surface patterns and textures can be produced by:

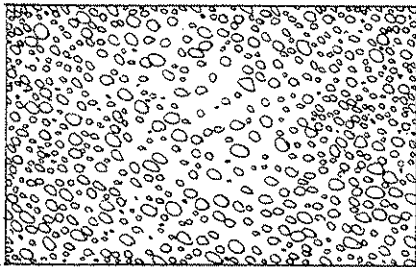
• Selection of the concrete ingredients

The color of concrete can be controlled with the use of colored cement and aggregates.

The aggregate can be exposed by scrubbing or hosing after the initial set of the concrete to remove the surface layer of cement paste. Chemicals can be sprayed on the forms to help retard the setting of the cement paste.



Exposed fine aggregate



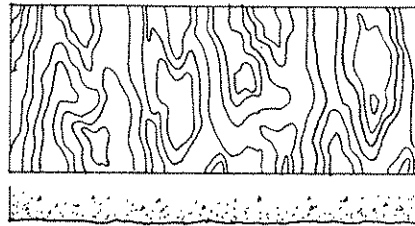
Exposed coarse aggregate

• The impressions left by the forms

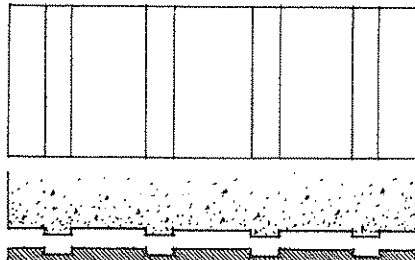
Plywood forms can be smooth or be sandblasted or wirebrushed to accentuate the grain pattern.

Sheathing lumber can be used to produce a board texture.

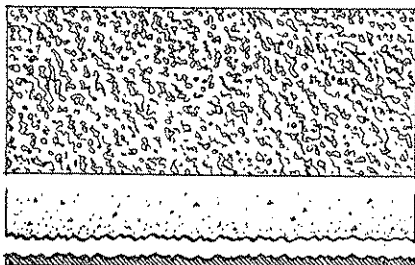
Metal or plastic formliners can produce a variety of textures and patterns.



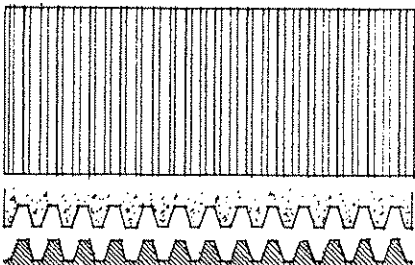
Sandblasted plywood



Board and batten pattern



Aggregate textured formliner

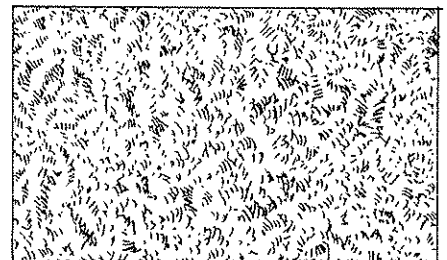


Ribbed texture formliner

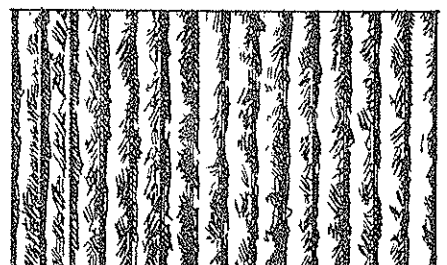
• Treatment after the concrete is set.

Concrete can be painted or dyed after it has set. The surface can be sandblasted, rubbed, or ground smooth.

Both smooth and textured surfaces can be bush or jack-hammered to produce coarser textures.

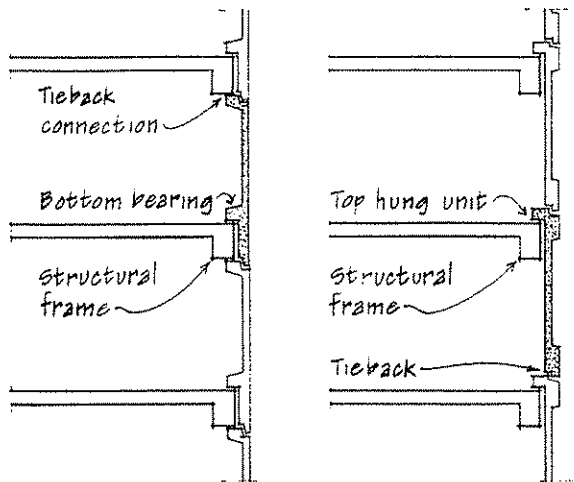


Bush hammered surface

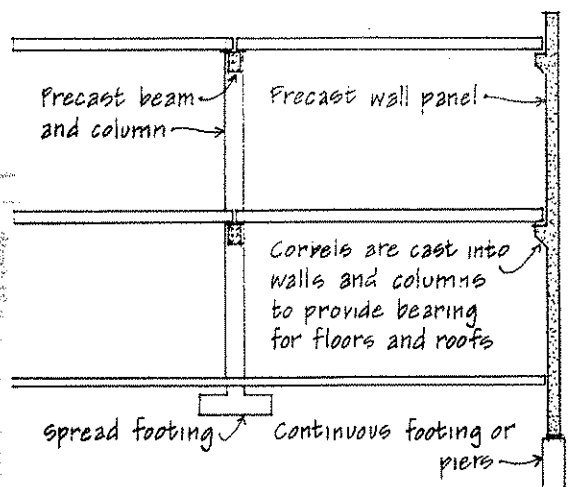


Ribbed surface bush hammered

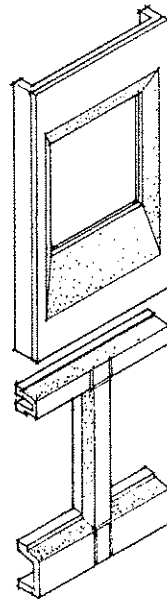
48 PRECAST CONCRETE WALLS



NONSTRUCTURAL WALL UNITS



LOADBEARING WALL UNITS

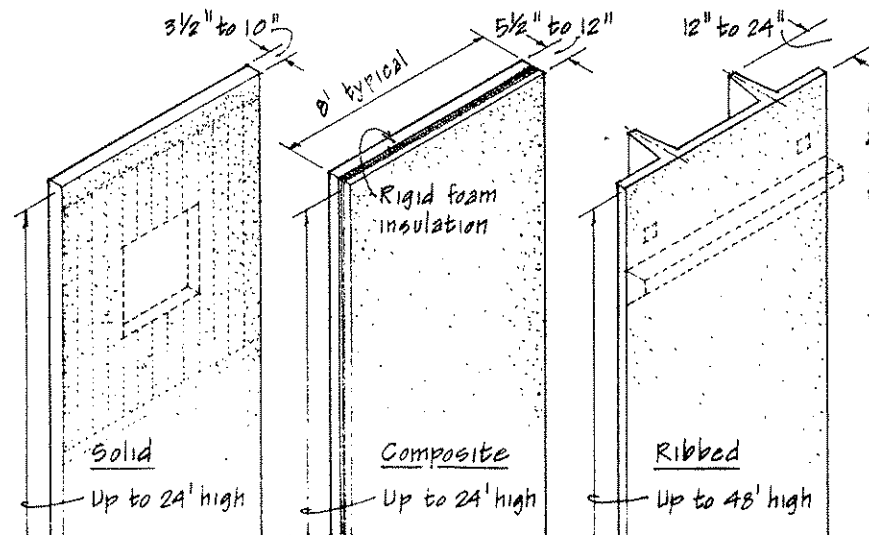


Precast concrete wall units may be used as nonbearing facing panels or as load-bearing structural elements. Nonbearing wall units are supported by a structural steel or concrete frame, and may be either top hung or bottom bearing. They are connected to the supporting frame with dowels grouted in position or with clip angles and bolts. Where there is a possibility of corrosion and staining, use stainless steel devices.

Instead of conventionally reinforced concrete, glass fiber reinforced concrete (GFRC) can be used to produce much thinner and lighter veneer panels.

Precast structural units can form bearing walls which are capable of supporting floor and roof systems of sitecast concrete, precast concrete, steel, or wood. Precast concrete columns, beams and slabs can be used with the walls to form an entirely precast structural system.

Structural precast concrete wall units may be of solid, composite, or ribbed construction. They may be prestressed or post-tensioned for greater structural efficiency, reduced panel thicknesses, and longer spans.



Window and door openings, corbels, and anchoring devices can be cast into the wall units, along with a variety of surface textures and patterns.

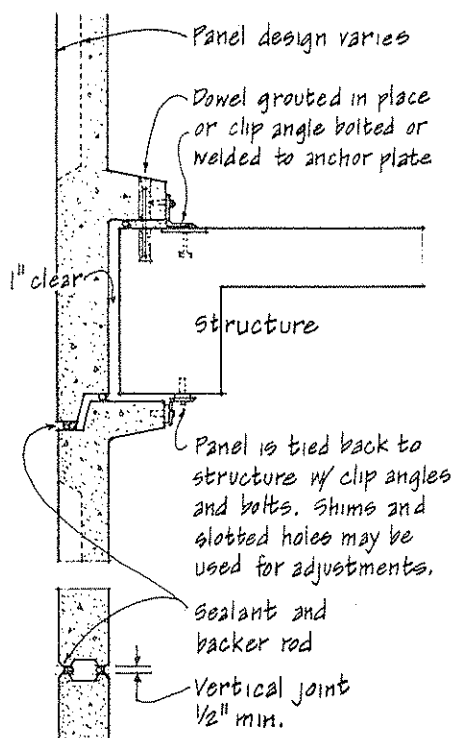
For preliminary sizing, the following sizes of precast columns can support the total floor and roof areas indicated.

10" x 10"	12" x 12"	16" x 16"
2000 S.F.	2750 S.F.	4500 S.F.

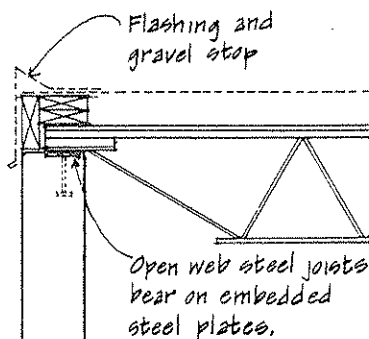
PRECAST CONCRETE WALL PANELS

PRECAST CONCRETE WALL CONNECTIONS

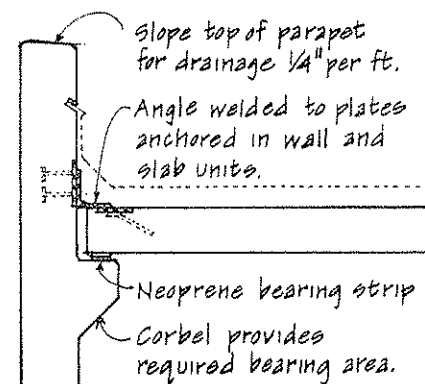
D.49



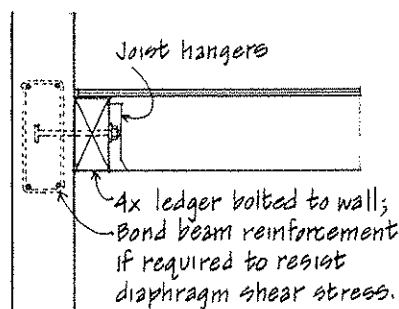
NONSTRUCTURAL WALL UNIT



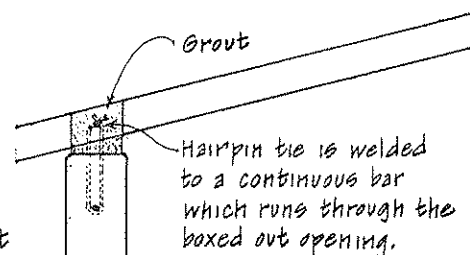
STEEL JOISTS



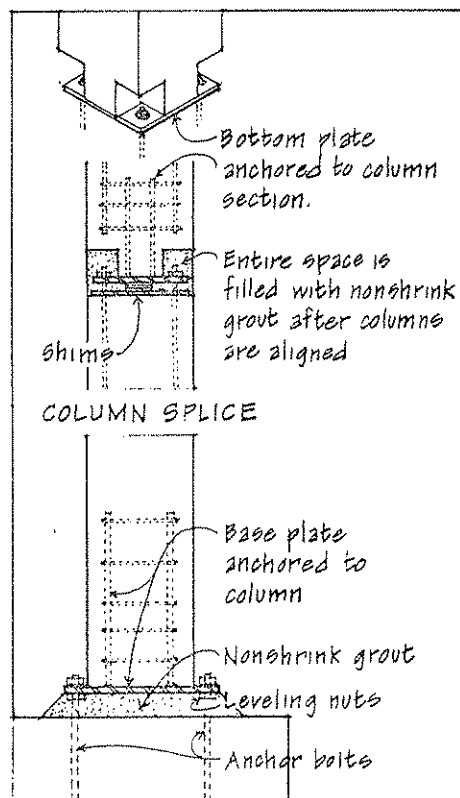
PRECAST CONCRETE SLAB



WOOD JOISTS

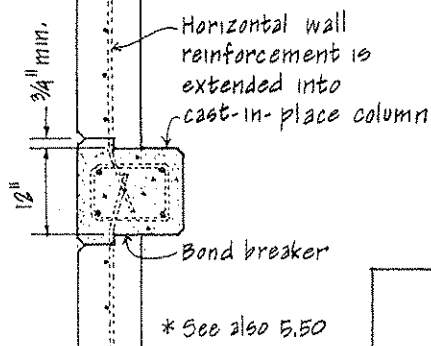


PRECAST CONCRETE SLAB

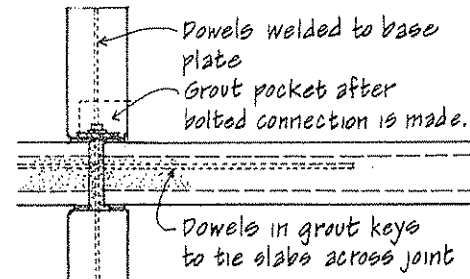


COLUMN BASE

The lateral stability of a precast concrete structure depends on how it is held together. Floors and roofs that serve as structural diaphragms must transfer their horizontal forces to the resisting walls. The wall panels, in turn, can be stabilized by columns or cross walls.

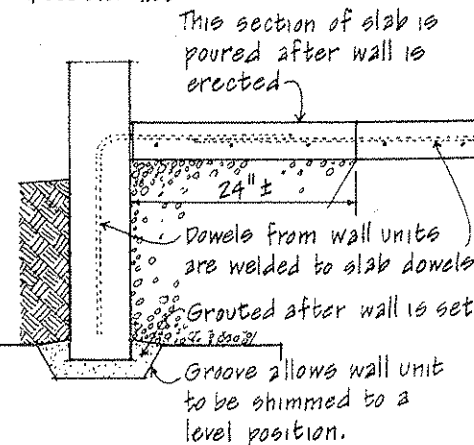


COLUMN CONNECTION



PRECAST CONCRETE SLAB

* See also 4.36



CONCRETE FOOTING

50 TILT-UP CONCRETE CONSTRUCTION

In tilt-up concrete construction, concrete wall panels are cast on-site in a horizontal position. The casting platform is usually the concrete ground slab for the building under construction, although earth, plywood, and steel molds can also be used. Depending on the wall finish desired and the presence of any projections, such as corbels or pilasters, the wall panels may be cast with their outside faces up or down.

Projections and the pickup devices are cast into the upper face.

Reveals and recessed steel plates may be cast into this face.

Concrete slab platform should be level and smoothly troweled. A bond breaking agent is used to ensure a clean lift.

Once the wall panels are cured to sufficient strength, they are lifted with a crane and set on their footings or piers. They are then temporarily braced until connections can be made to the remaining part of the structure.

Full height panels may be up to 15' wide.

Spandrel units can cantilever and span large openings.

The wall panels must be designed to withstand the stresses of being lifted and moved, which can exceed the in-place loads.

The floor and roof connections are similar to those shown on 4.36 and 5.49. Below are typical wall panel connections to columns and to each other.

Extend horizontal wall reinforcement into cast-in-place column

Vertical reinf. Ties

Precast walls

Sealant and backer rod

1/2"

Quirk miter

PRECAST CONCRETE WALL DETAILS

Precast wall

Weld plate anchored in wall to column angle

Precast column

Extend horizontal wall reinforcement into cast-in-place column

1/2" min.

Drypack grout

3/4" min.

12" min.

3/4" min.

Lap horizontal wall reinforcement in cast-in-place splice.

Extend horizontal wall reinforcement into cast-in-place corner splice

Precast walls

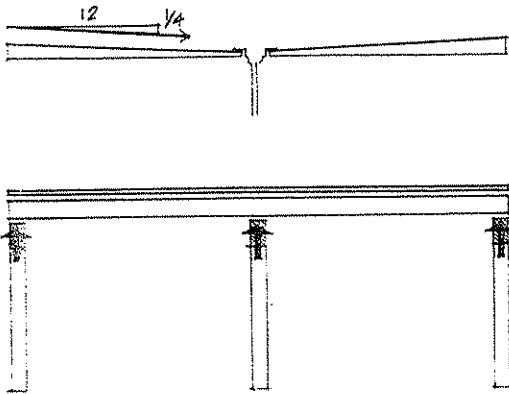
ROOF SYSTEMS

The roof system functions as the primary sheltering element for the interior spaces of a building. Its form and construction should control the flow of water as well as the passage of water, air, heat and cold. Like floor systems, a roof must be structured to span across space and carry both its own weight and live loads such as wind and snow. The gravity loads for a building begin with the roof system. Its structural layout must therefore correspond to that of the wall and column systems through which its loads are transferred down to the foundation system.

Depending on the type of construction required by the building code, the roof structure and the roofing material itself may have to be fire-resistant. In addition, the depth of the roof system may have to accommodate mechanical and electrical equipment. Because of its varied functional tasks spread over a large area, the roof system is potentially the most expensive system of a building. Economy of erection and maintenance, durability, and thermal insulation value should all be considered in the choice of a roof system and its materials.

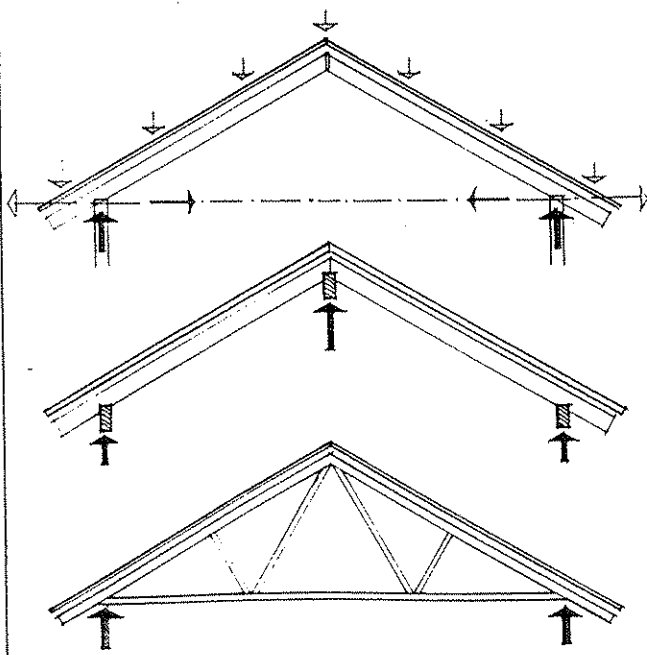
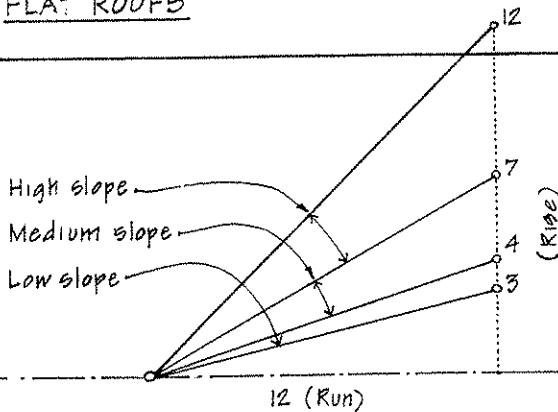
The form of a roof system—whether flat or sloped, gabled or hipped—has a vital impact on a building's visual image. How a roof form is structured, in turn, affects the choice of roofing material, the interior ceiling system, and the layout of a building's interior spaces. Long roof spans would open up a more flexible interior space while shorter roof spans might suggest more rigidly defined spaces.

6.2 COMPARATIVE ROOF SLOPES



FLAT ROOFS

- Minimum recommended slope: $\frac{1}{4}$ " per foot.
- Slope may be achieved by sloping the structural members or by tapering the roof deck or rigid insulation.
- Slope usually leads to interior drains; perimeter scuppers can be used as overflow drains.
- Flat roofs can efficiently cover a building of any horizontal dimension, and can be designed to serve as outdoor space.
- Roof structure may consist of:
 - Joists and sheathing
 - Beams and decking
 - Flat trusses
 - Concrete slabs
- Flat roofs require continuous membrane roofing.

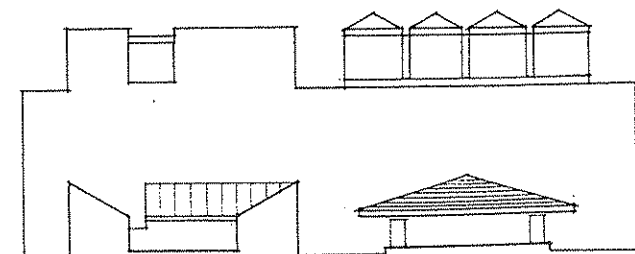
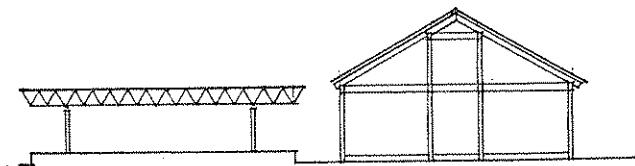
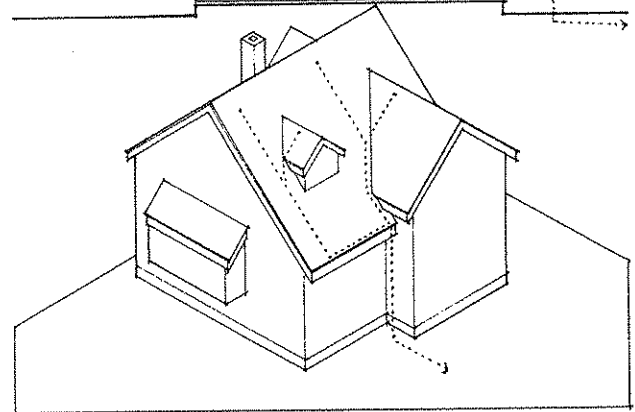
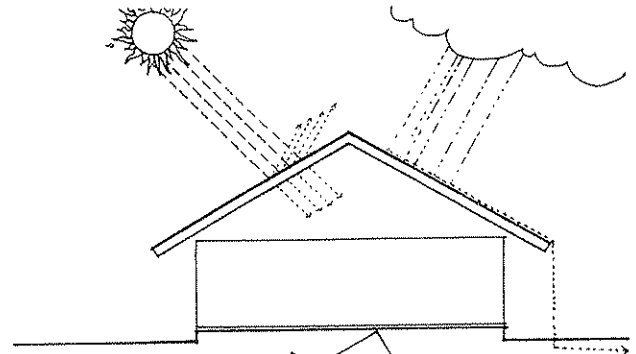
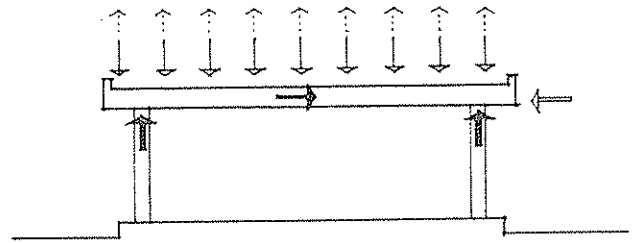


SLOPING ROOFS

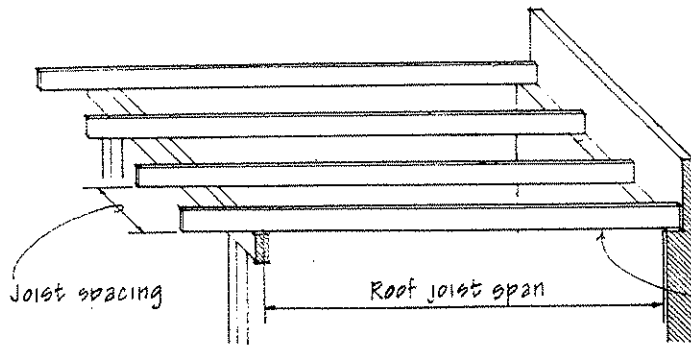
- Sloping roofs may be categorized into:
 - Medium to high slope - 4:12 to 12:12
 - Low slope - up to 3:12
- Sloping roofs shed water easily to eave gutters.
- Roof height and area increase with its horizontal dimension.
- Space under the roof may be usable.
- Sloping roofs may have a structure of:
 - Rafter and sheathing
 - Beams, purlins, and decking
 - Trusses
- Medium and high slope roofs may be covered with shingles, tiles, or sheet materials.
- Low slope roofs require roll or continuous membrane roofing; some shingle and sheet materials may be used on 3-in-12 pitches.
- The roof slope also affects the design loads and the requirements for underlayment and eave flashing.
- Sloping roof planes may be combined to form a variety of roof forms. See 6.6-6.7.

ROOF DESIGN AND CONSTRUCTION FACTORS

- Roof structure must be designed to carry:
 - Dead loads: Roof structure, deck, insulation, roofing, and any equipment located on top of or suspended from roof
 - Live loads: Accumulated rain, snow and ice, and traffic, if any
 - Wind loads: Pressure or suction from wind. (See 1.14)
- The type of roofing required for the roof slope:
 - Shingles, tiles, sheet, or membrane. (See Chapter 8)
- The degree of protection required against:
 - Surface water from the outside
 - Water vapor diffusion from the inside
 - Moist air flow
 - Heat flow and solar radiation
- The drainage pattern of the roof form:
 - The location of roof drains, scuppers, gutters, and downspouts. (See 8.14)
- Flashing requirements: (See 8.15-8.16)
 - Along ridges, hips, and valleys
 - Along eaves, rakes, and intersection with vertical surfaces
 - Around roof openings.
- The effect of the roof support pattern on interior spaces:
 - Point or linear supports (columns or bearing walls)
 - Length of roof spans
 - Bay sizes and proportions
 - The roof form, if its underside is exposed
 - The types of ceilings that may be supported.
- The effect of the roof form on the building:
 - Flat or sloped roof forms
 - Single or multiple forms
 - Roof edge conditions
 - Concealed behind a parapet
 - Exposed and flush with or overhanging the wall planes.



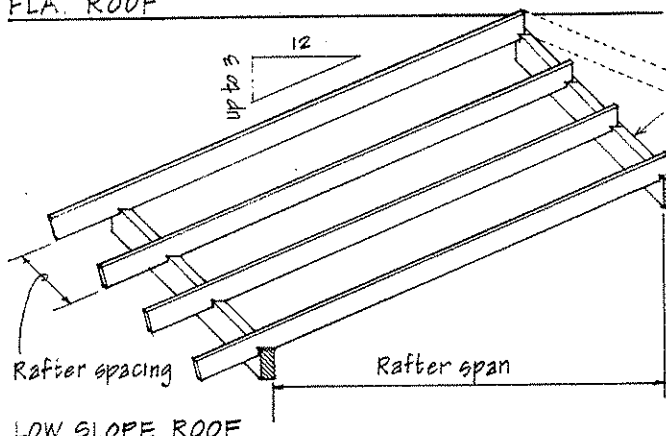
6.4 WOOD ROOF JOISTS AND RAFTERS



FLAT ROOF

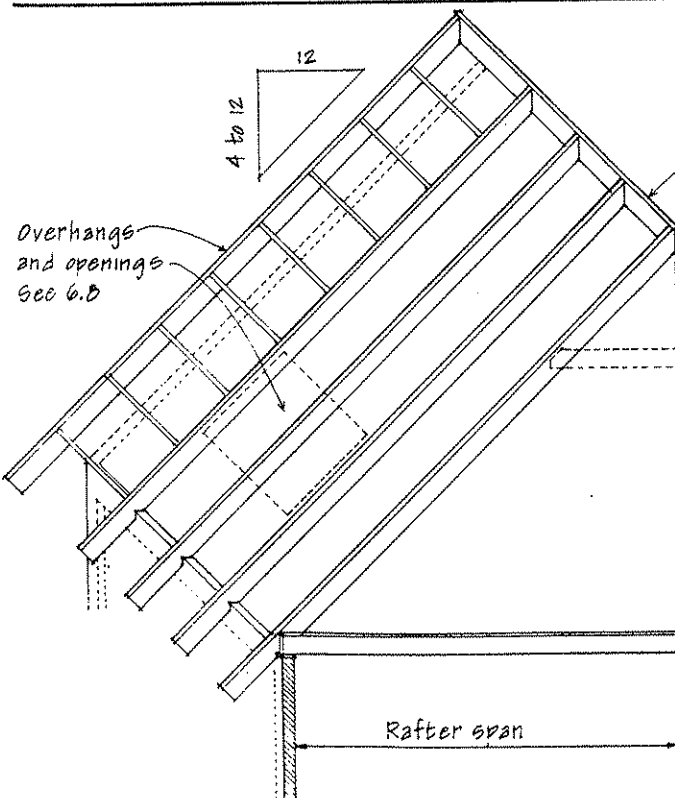
Wood joist or rafter framing systems for roofs are similar in nature to wood joist floor systems. See 4.4.

- Joists or rafters are spaced 12", 16", or 24" o.c. depending on the roof load and the spanning capability of the sheathing.
- Joists and rafters may be oversized to accommodate the required thermal insulation.
- A ceiling finish is usually applied directly to the underside of roof or ceiling joists.



LOW SLOPE ROOF

- Members supporting rafters with a slope of less than 3:12 must be designed as beams.



MEDIUM OR HIGH SLOPE ROOF

- If ceiling joists are used, attic space may accommodate mechanical or electrical equipment.

- Ridge board keeps the rafter ends aligned. A structural ridge beam is required if ceiling joists do not tie the rafters between the exterior wall supports.

- Collar beam within the upper 1/3 of the roof height. See 6.6

- With sufficient headroom, natural light, and ventilation, attic space may be habitable.

- Ceiling (or attic floor) joists are nailed to the rafters to form a continuous tie between exterior walls.

WOOD RAFTER SPAN TABLE

D.5

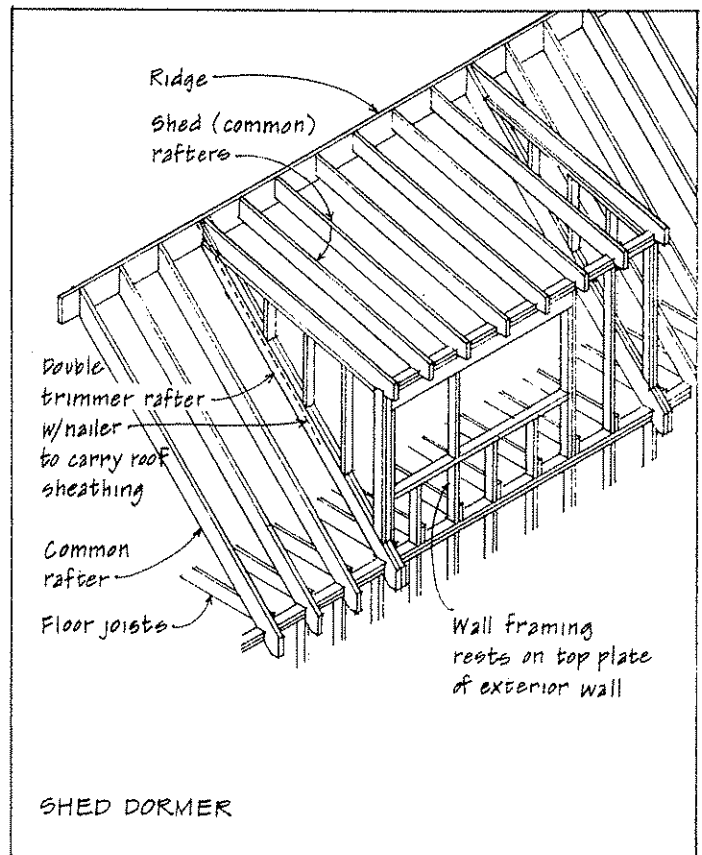
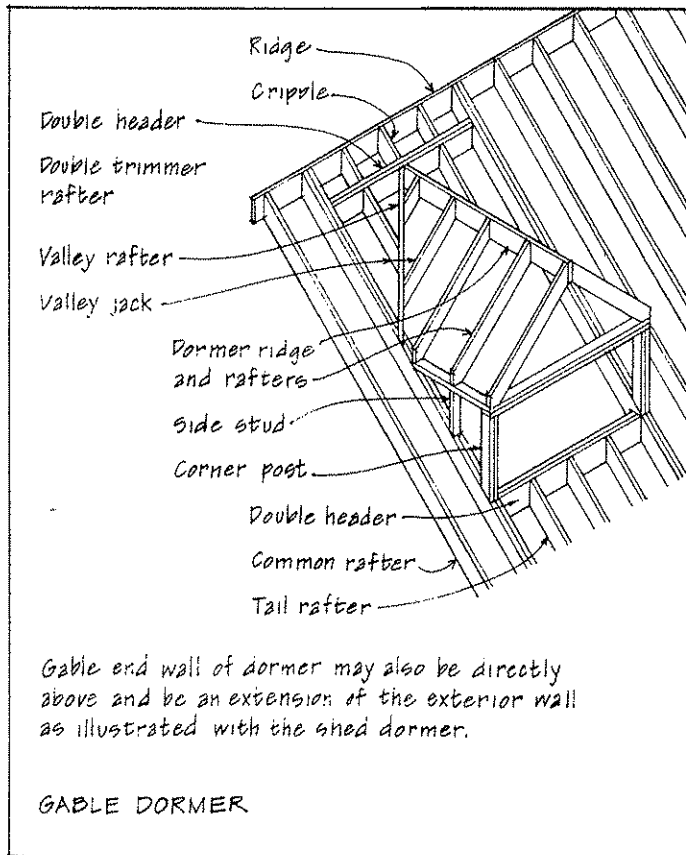
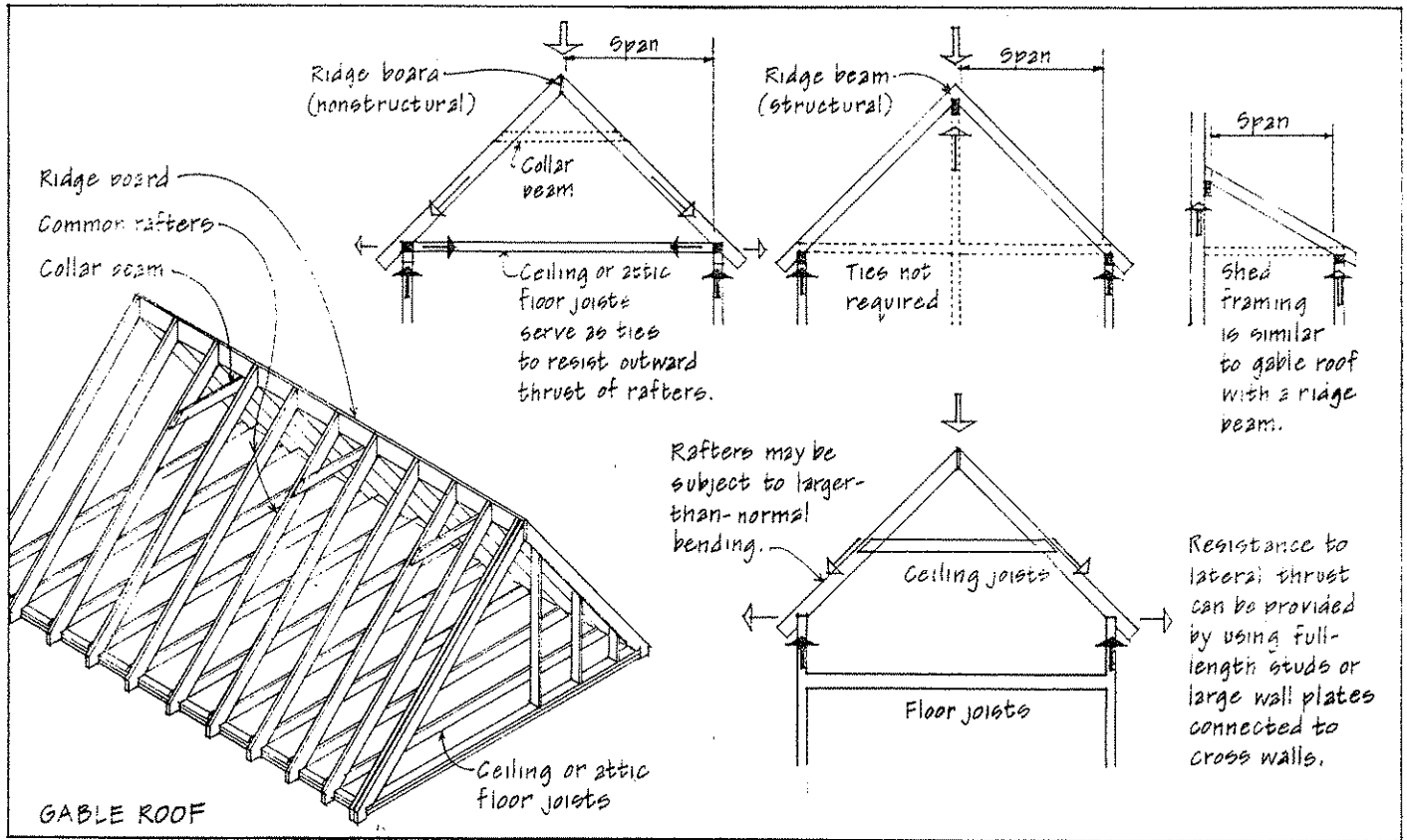
The rafter span table below is for preliminary sizing of members only. It assumes that the rafters have simple spans.

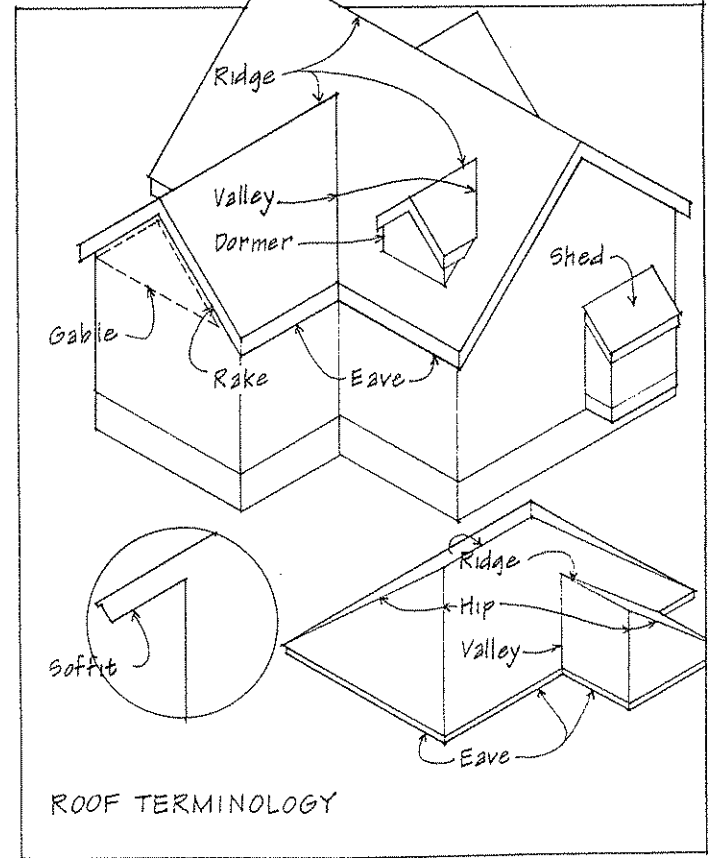
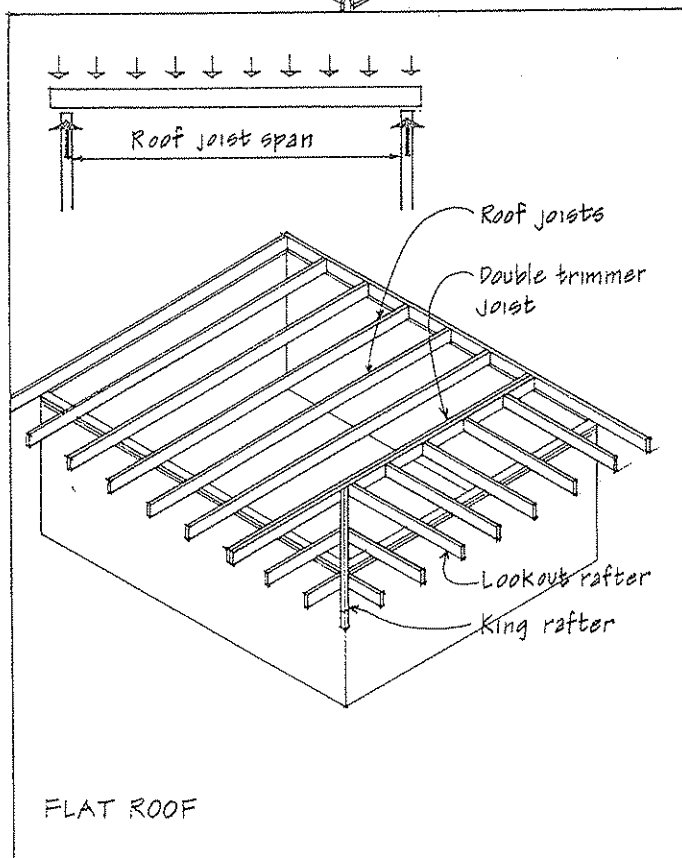
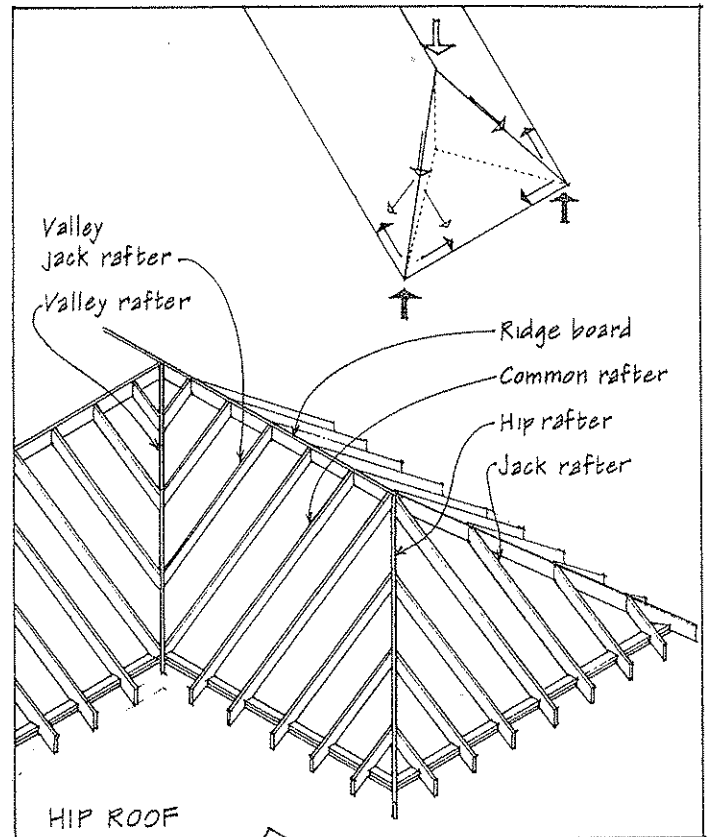
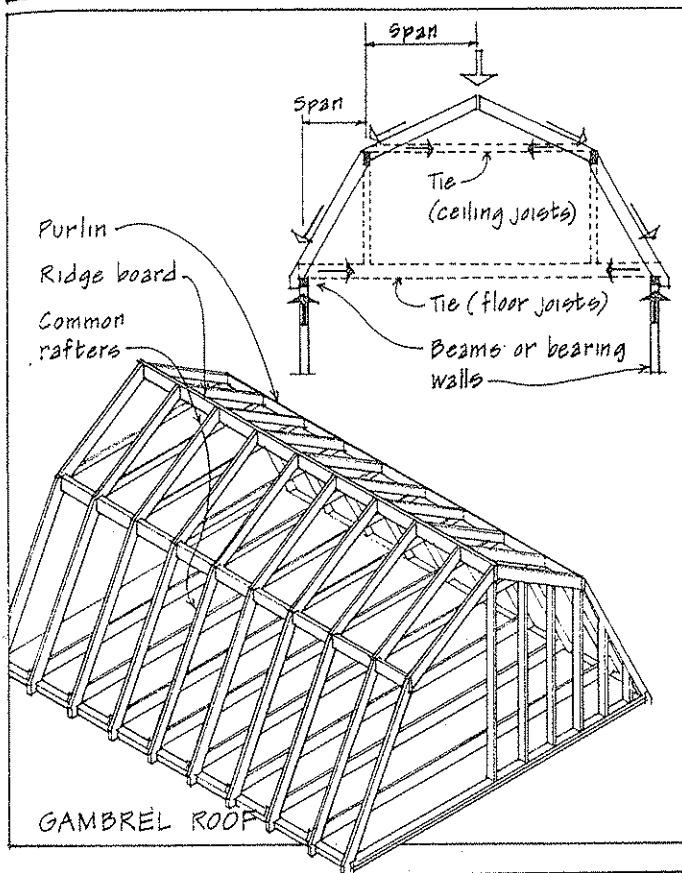
SIZE nominal	SPACING center to center	SPAN AS LIMITED BY DEFLECTION*		SPAN AS LIMITED BY BENDING			
		E = 1,200,000 psi	1,400,000 psi	F _b = 1000 psi	1200 psi	1400 psi	1600 psi
		Live Load: 20 lbs. per S.F.					
2 x 4 5x10	12"	6'-9"	7'-2"	8'-1"	8'-10"	9'-6"	10'-2"
	16"	6-2	6-6	7-0	7-8	8-3	8-10
	24"	5-5	5-9	5-9	6-4	6-10	7-3
2 x 6	12	10-5	11-0	12-4	13-6	14-7	15-7
	16	9-7	10-1	10-9	11-10	12-9	13-8
	24	8-5	8-10	8-11	9-9	10-6	11-3
2 x 8 3x10	12	13-10	14-7	16-3	17-10	19-3	20-7
	16	12-8	13-4	14-3	15-7	16-10	18-0
	24	11-2	11-9	11-9	12-11	13-11	14-11
2 x 10	12	17-5	18-4	20-4	22-4	24-1	25-9
	16	15-11	16-9	17-10	19-7	21-2	22-7
	24	14-1	14-10	14-10	16-3	17-6	18-9
2 x 12	12	20-11	22-0	24-4	26-8	28-10	30-10
	16	19-2	20-2	21-5	23-6	25-5	27-2
	24	16-11	17-10	17-10	19-6	21-1	22-6
2 x 14	12	24-4	25-7	28-4	31-0	-	-
	16	22-5	23-7	25-0	27-4	29-6	-
	24	19-10	20-10	20-9	22-9	24-7	26-4
Live Load: 30 lbs. per S.F.							
2 x 6	12"	9-8	10-2	11-0	12-0	13-0	13-10
	16"	8-10	9-3	9-7	10-6	11-4	12-1
	24"	7-9	8-2	7-10	8-7	9-4	9-11
2 x 8	12	12-10	13-6	14-6	15-10	17-0	18-4
	16	11-8	12-4	12-8	13-10	15-2	16-0
	24	10-3	10-10	10-5	11-5	12-4	13-2
2 x 10	12	16-1	17-0	18-2	19-11	21-6	23-0
	16	14-9	15-6	15-11	17-5	18-10	20-2
	24	13-0	13-8	13-2	14-5	15-7	16-8
2 x 12	12	19-5	20-5	21-10	23-11	25-10	27-7
	16	17-9	18-9	19-2	21-0	22-8	24-3
	24	15-8	16-6	15-10	17-4	18-9	20-0
2 x 14	12	22-7	23-10	25-5	27-10	30-0	-
	16	20-9	21-10	22-4	24-5	26-5	28-3
	24	18-4	19-4	18-6	20-3	21-11	23-5

* Maximum allowable deflection = $1/360$ of span.

- E = modulus of elasticity; F_b = allowable unit stress in bending; both vary according to the species and grade of lumber used.
- Rafters are often oversized to accommodate required thermal insulation.

6 WOOD RAFTER ROOF FORMS





8. WOOD RAFTER FRAMING

Rake overhangs are built with lookout rafters framed into a double common rafter and bearing on the top plate of the gable end wall.

Roof openings are similar to joist floor openings. See 4.10.

Toenail rafter to top plate w/ 3-8d or use a framing anchor

Metal strap is used for resistance to uplift

Face nail ceiling joist to rafter w/ 3-16d; toenail to plate w/ 3-8d

RAFTER FRAMING

Critical depth of rafters

Ceiling joists

Eave detail varies; see facing page

Rafters may bear on the double top plate of a stud wall or on a single plate when attic floor joists are supported by the stud wall.

RAFTER SUPPORT CONDITIONS

Ventilation at peak may be provided with a continuous ridge vent or by a louvered vent in the gable end walls.

3-10d or 4-8d

Collar beams tie pairs of rafters together and help them resist uplift in high winds; 1x6 or 8 (use 2x if ceiling is attached).

Rafters are framed opposite each other at the ridge board; face or toenail w/ 2-10d for 1x ridge or 2-16d for 2x ridge.

Ridge board keeps rafters aligned; 1x material min. (2x material is better); should be as deep as cut ends of rafters.

Use 2 2x ledger where rafters meet a stud wall.

Subfloor

Solid blocking

Attic floor joists

Double top plate

Stud wall

WOOD RAFTERS: ROOF EDGE DETAILS

Rake fascia and trim may extend beyond eave fascia

Exposed rafters or sloping soffit

Closed rake

Narrow soffit

Rake fascia

Soffit or cornice return

Wide soffit

It is important to consider how the roof eave detail turns the corner and meets the rake detail.

Roof sheathing

Metal drip edge

Blocking

Rake trim and fascia

Fly rafter

Lookout rafter

Soffit

Frieze board

Gable end wall

RAKE OVERHANG

Roof sheathing

Metal drip edge

Rafter

Rake trim

Blocking

Frieze board

Gable end wall

CLOSED RAKE

Blocking w/ screened vent holes

Roof sheathing

Exposed rafters

Fascia Header

EXPOSED RAFTERS

Rafter

Top plate

Ledger

Roof sheathing

Frieze board

Lookout soffit

Vent strip

Fascia Header

VENTED SOFFIT (Wide)

Rafter

Top plate

Wall sheathing

Frieze board

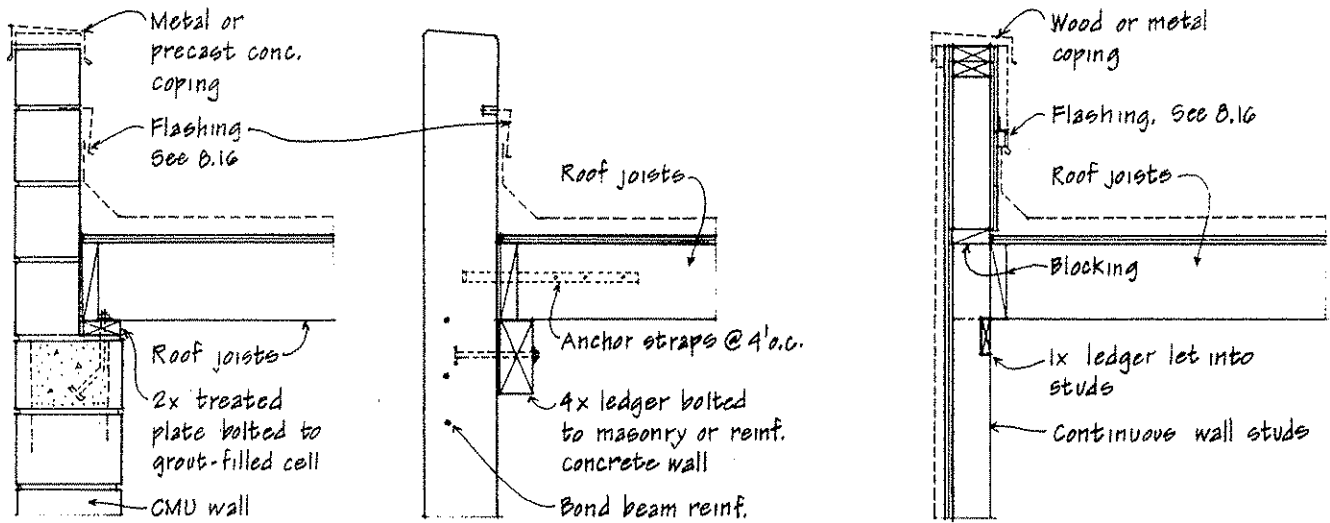
Soffit

Continuous vent strip

Fascia Header

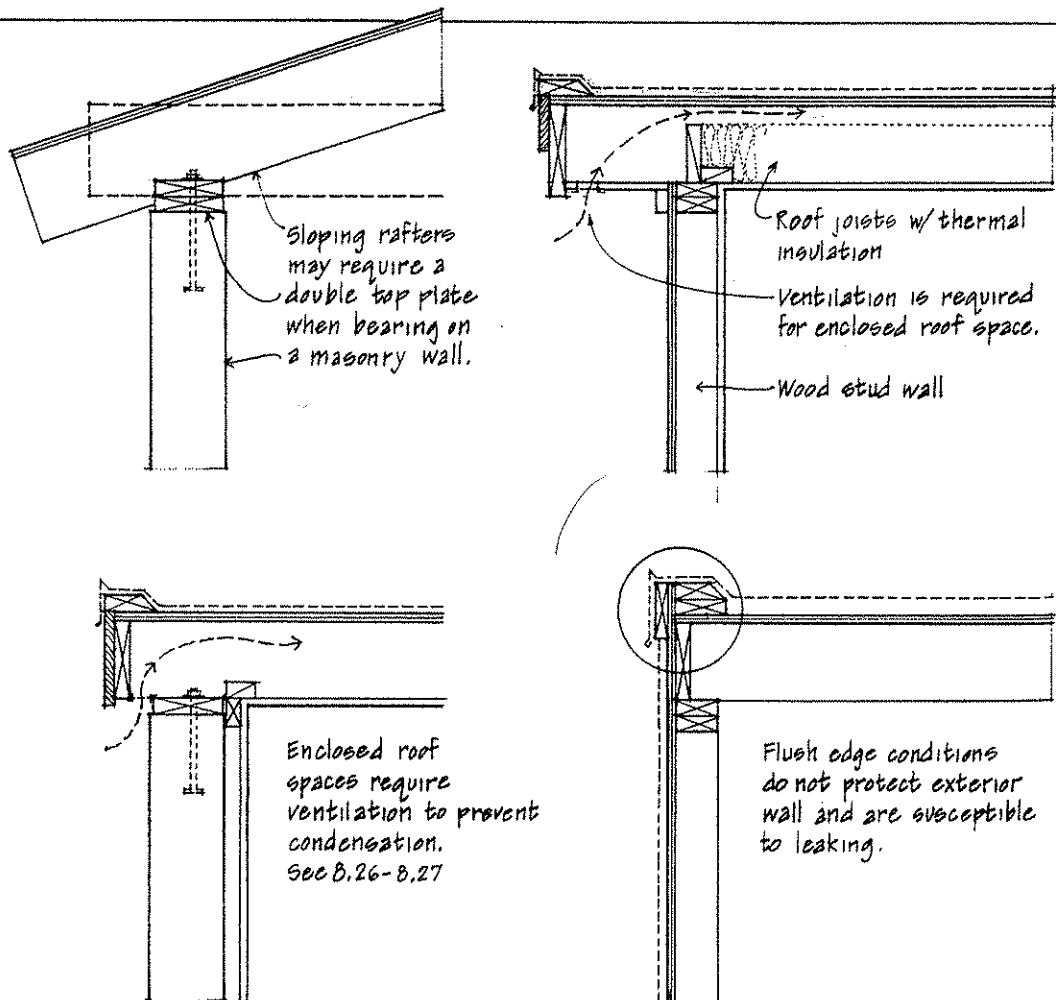
VENTED SOFFIT (Narrow)

10 WOOD RAFTERS: ROOF EDGE DETAILS



PARAPET WALLS

Parapet walls are intended to prevent the spread of fire from one building to another. Check the local building code for height and construction requirements.



FLAT ROOF JOISTS

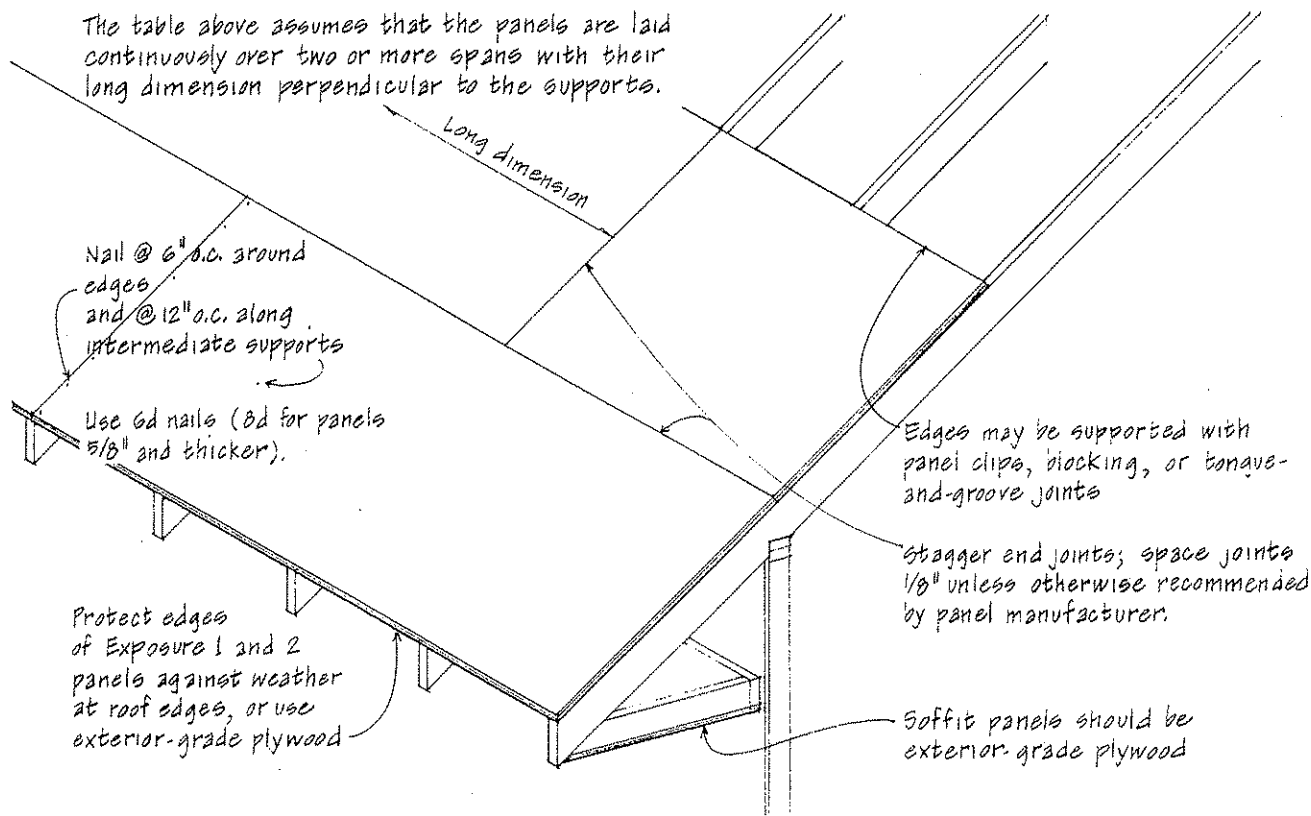
WOOD RAFTERS: SHEATHING

PANEL ROOF SHEATHING

Panel Identification Index	Panel thickness (in.)	Maximum Span (in.)		Total Live Load (lbs/s.f.)
		w/ edge support	w/o edge support	
12/0	5/16	12		150
16/0	5/16, 3/8	16		75
20/0	5/16, 3/8	20		65
24/0	3/8	24	16	50
24/0	1/2	24	24	50
32/16	1/2, 5/8	32	28	40
40/20	5/8, 3/4, 7/8	40	32	35
48/24	3/4, 7/8	48	36	35

A panel's span rating can be determined from its identifying grade stamp

The table above assumes that the panels are laid continuously over two or more spans with their long dimension perpendicular to the supports.



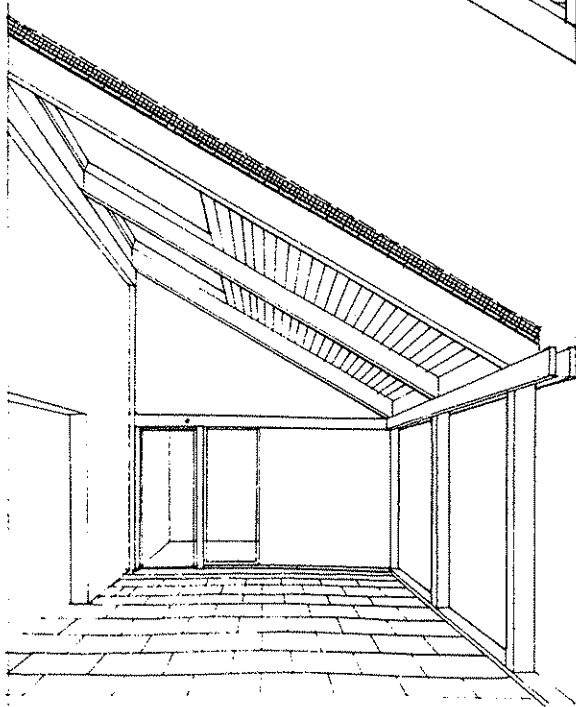
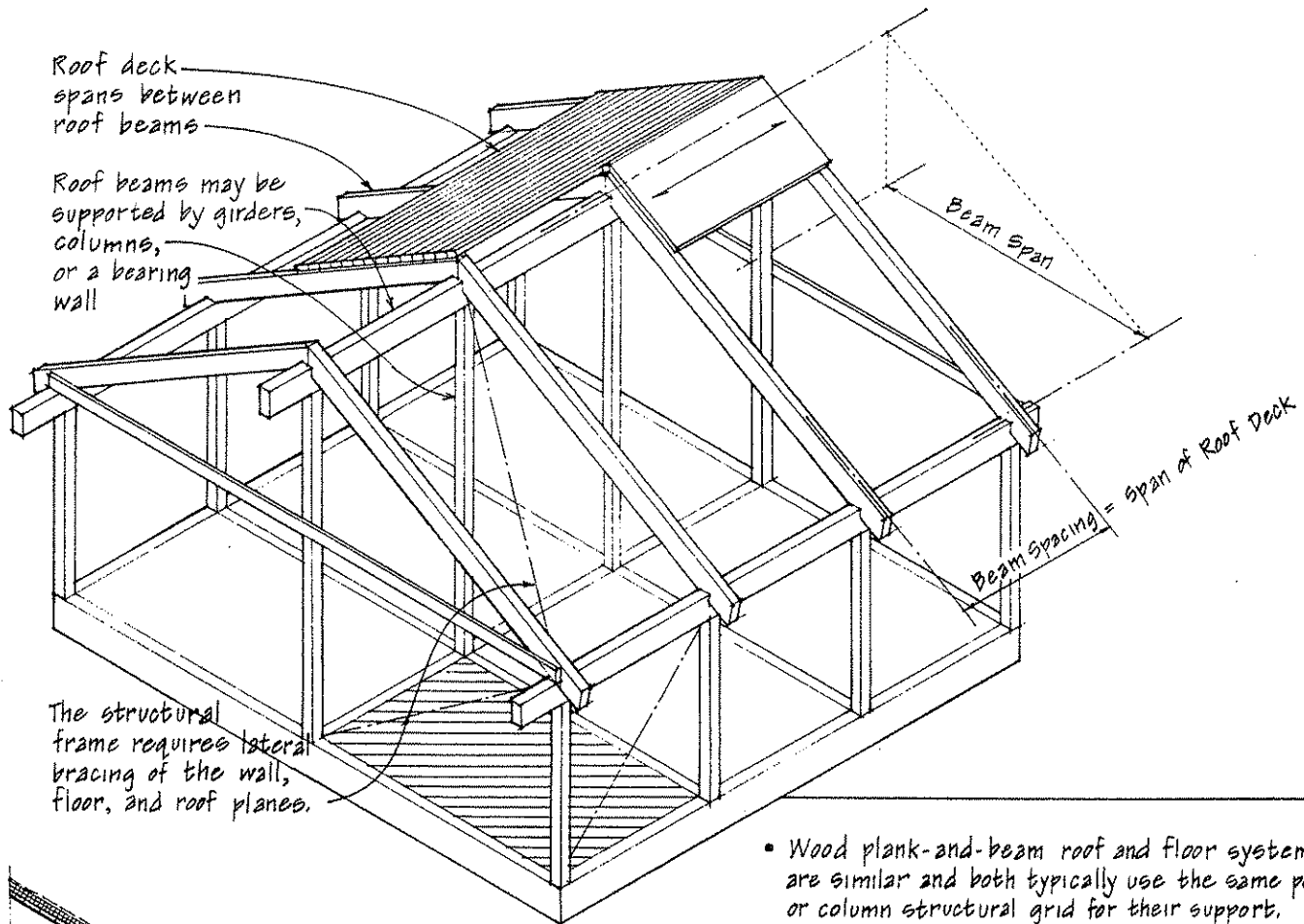
Sheathing over wood rafters typically consists of performance-rated plywood or nonveneer panels. These panels may be exterior grade plywood, or Exposure 1 (exterior glue) or Exposure 2 (intermediate glue) panels.

Panel sheathing enhances the stiffness of the roof framing and provides a solid base for the application of various roofing materials. Sheathing and underlayment requirements should be in accordance with the recommendations of the roofing manufacturer.

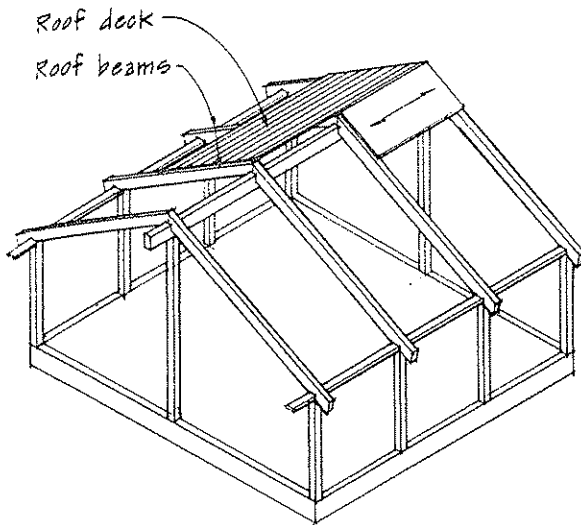
In damp climates not subject to blizzard conditions, spaced sheathing of 1x4 or 1x6 boards may be used with wood shingle or shake roofing. See 8.8-8.9.

B.12

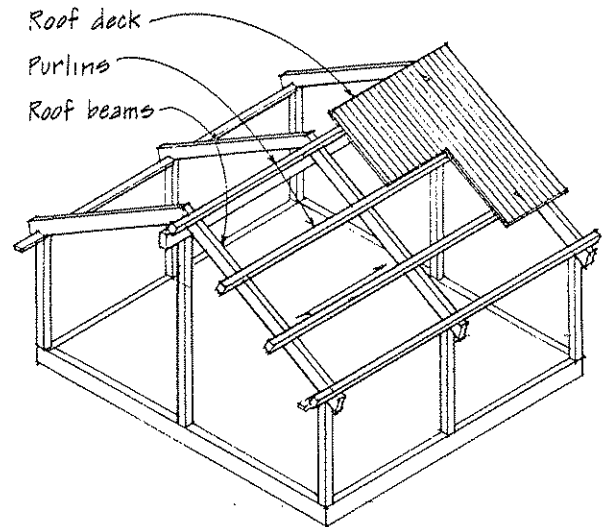
WOOD PLANK AND BEAM ROOF SYSTEM



- Wood plank-and-beam roof and floor systems are similar and both typically use the same post or column structural grid for their support, See 4.14.
- The size and spanning capability of the roof beams are related to:
 - The roof load
 - The beam spacing
- The beam spacing, in turn, is related to the thickness and spanning capability of the wood planking used. The tables on 4.15 and 4.19 can be used to estimate the sizes of roof beams and planking.
- The plank-and-beam framing is often left exposed with rigid thermal insulation being applied over the roof deck and a vapor barrier. Exposed structures require thoughtful detailing of connections, the use of quality materials, and careful workmanship.
- Plank-and-beam framing offers no concealed spaces for overhead ductwork, pipes, or wiring, except when a layered structure or spaced structural members are used.

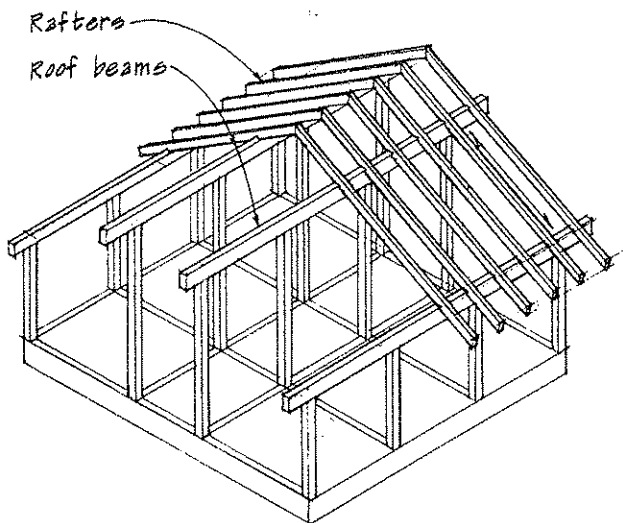


The roof beams are spaced 6' to 8' o.c. and spanned with solid or glue-laminated wood planks. The beams may be supported by girders, columns, or a masonry or concrete bearing wall.

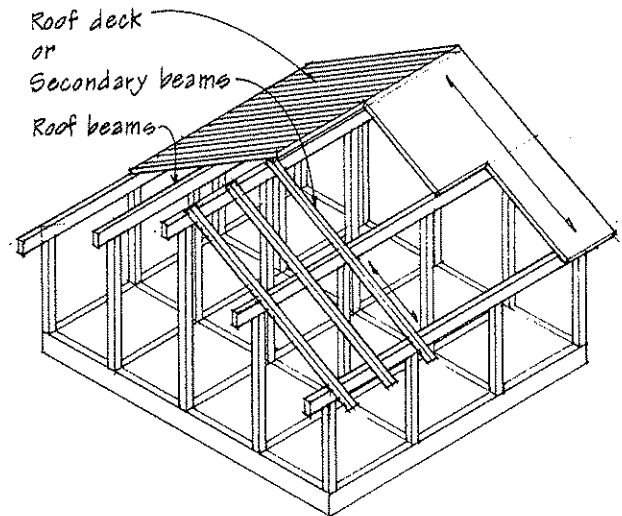


In this two-layer system, the roof beams may be spaced further apart and support a series of purlins. These purlins, in turn, are spanned with wood planks or a rigid, sheet roofing material.

ROOF BEAMS PARALLEL WITH THE SLOPE



In this example of a two-layer structure, the roof beams support a conventional system of wood rafters.

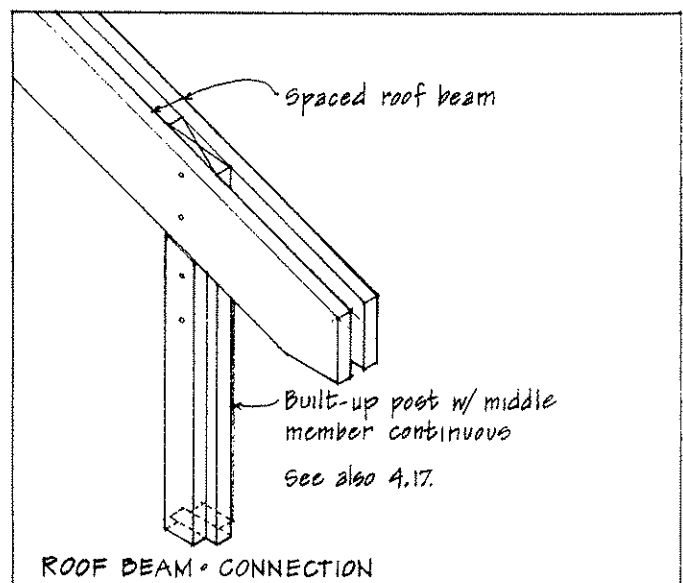
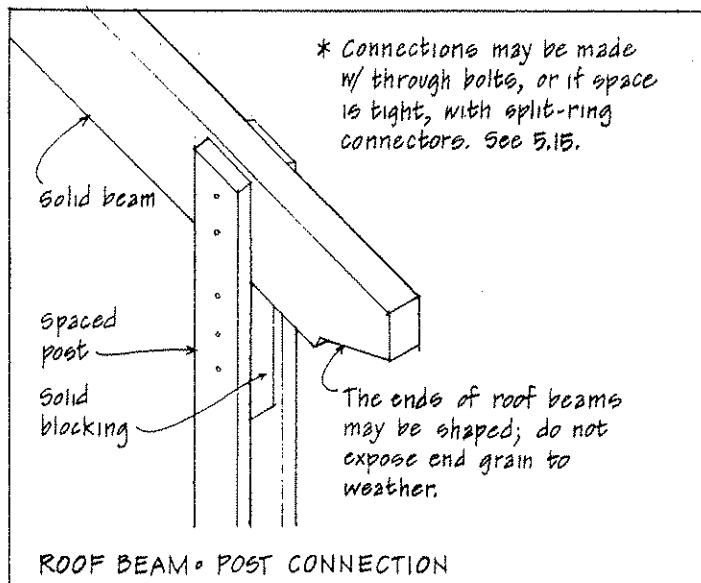
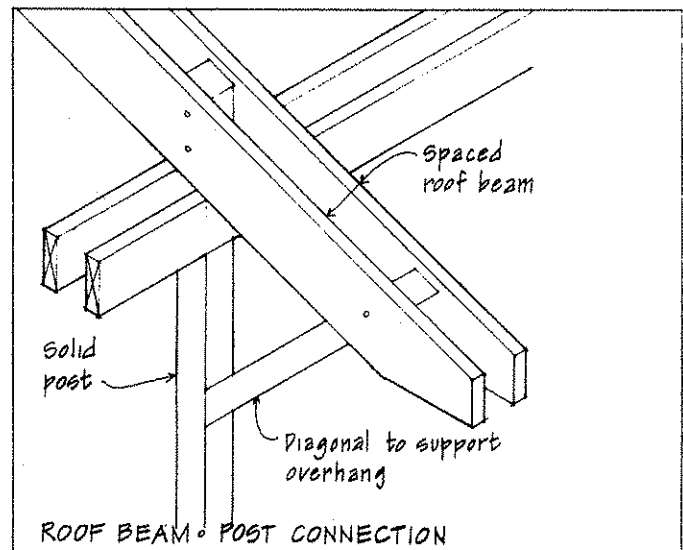
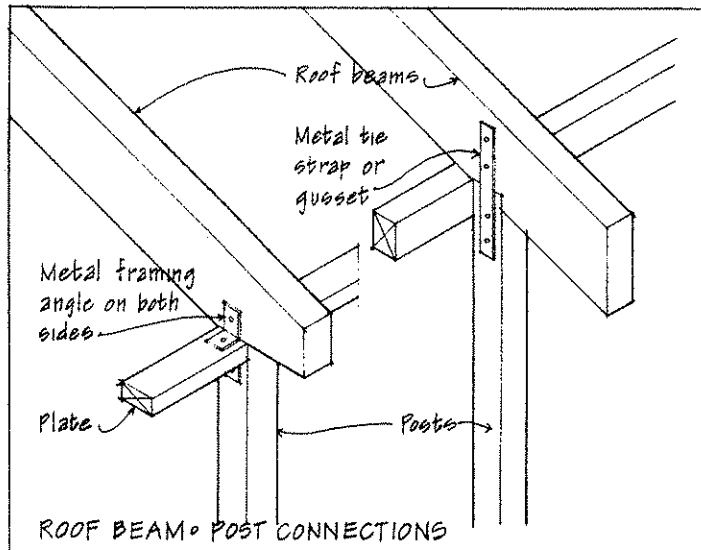
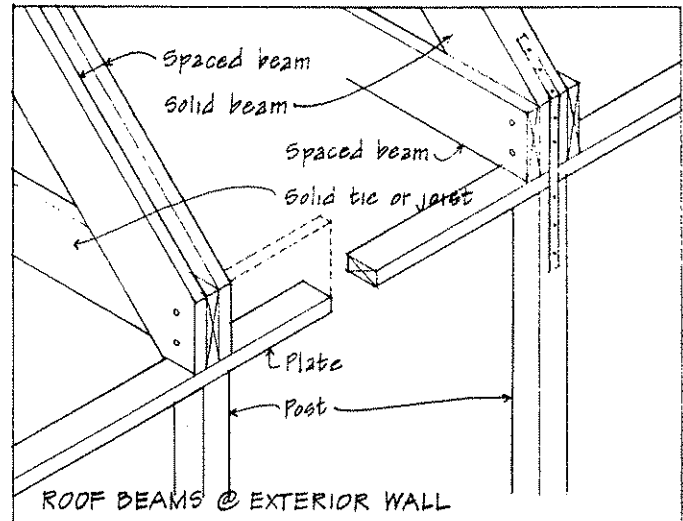
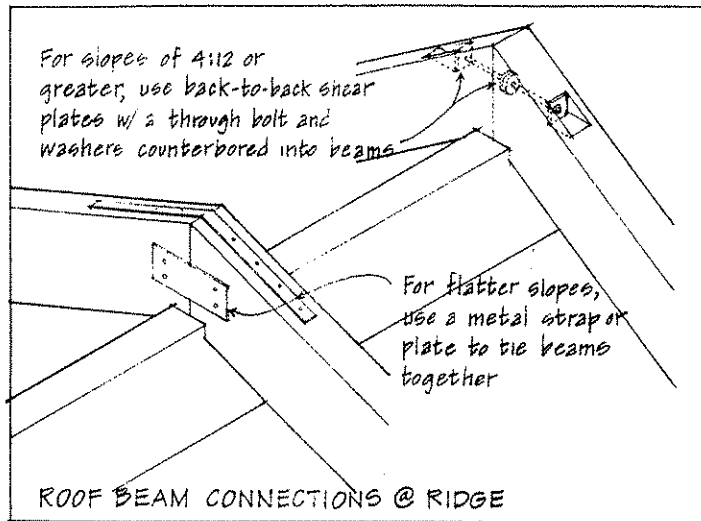


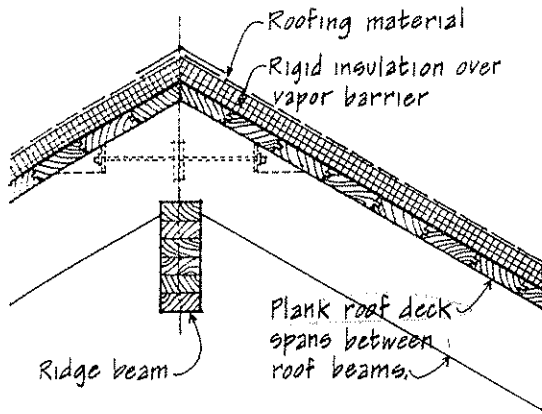
The roof beams may be spaced close enough to be spanned with wood planks. Spaced further apart, the beams can support a series of secondary beams parallel with the slope.

ROOF BEAMS PERPENDICULAR TO SLOPE

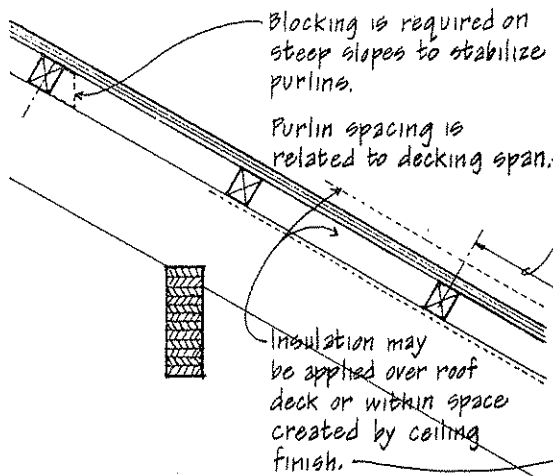
Illustrated above are alternatives for the framing of a plank-and-beam roof structure. They differ in the direction and spacing of the roof beams, the elements used to span the beams, and the overall depth of the construction.

4.14 WOOD ROOF BEAM CONNECTIONS

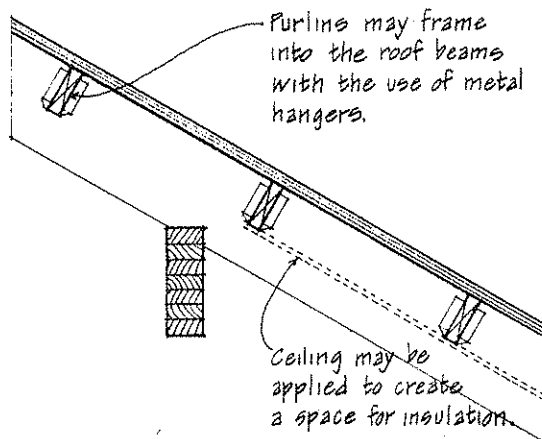




ROOF SECTION @ RIDGE

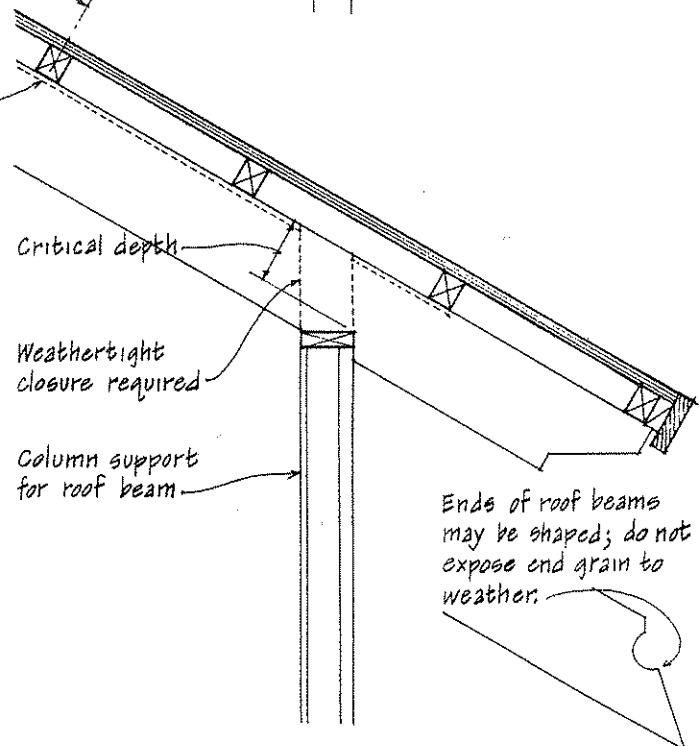
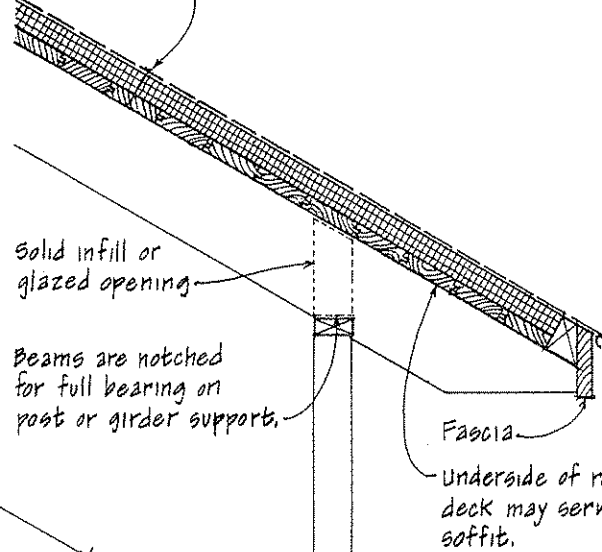


ROOF SECTION



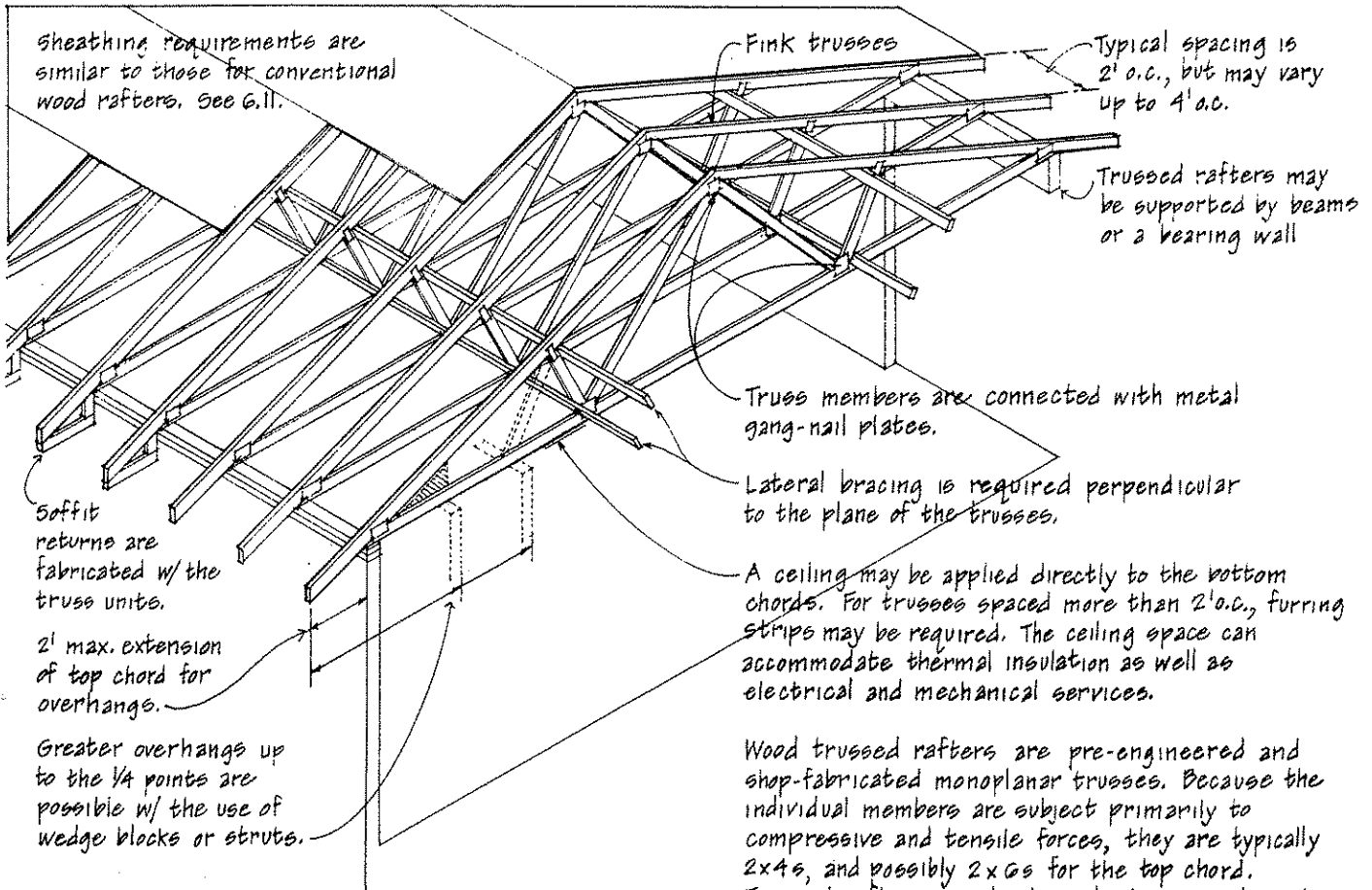
ROOF SECTION

Roofing material must be secured w/ fasteners long enough to penetrate through the insulation and well into the planking.

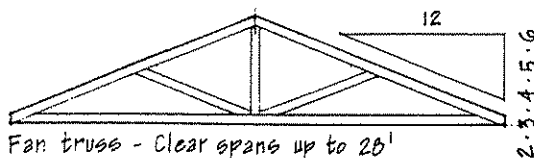


.16 WOOD TRUSSED RAFTERS

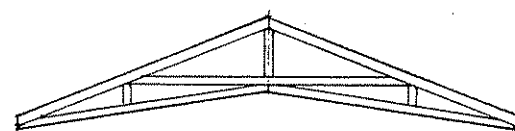
Sheathing requirements are similar to those for conventional wood rafters. See G.11.



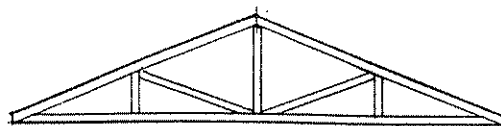
Wood trussed rafters are pre-engineered and shop-fabricated monoplanar trusses. Because the individual members are subject primarily to compressive and tensile forces, they are typically 2x4s, and possibly 2x6s for the top chord. Trussed rafters are best used when a rectangular plan requires long spans (over 18') and a quantity of a single truss type. In addition to the Fink truss illustrated above, other types are available. Consult the manufacturer for spans, allowable loads, and details.



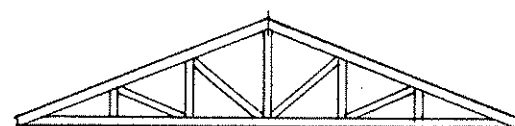
Fan truss - Clear spans up to 25'



Scissors truss - Clear spans up to 50'



Howe truss - Clear spans up to 50'



6-panel Howe truss - Clear spans up to 70'



Monopitch truss - Clear spans up to 40'



Flat Pratt truss - Clear spans up to 70'

TRUSS TYPES

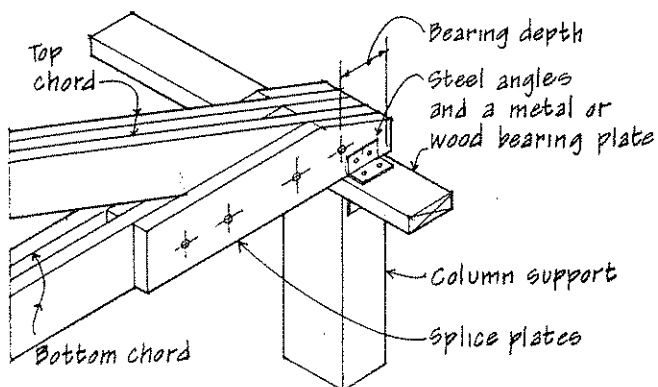
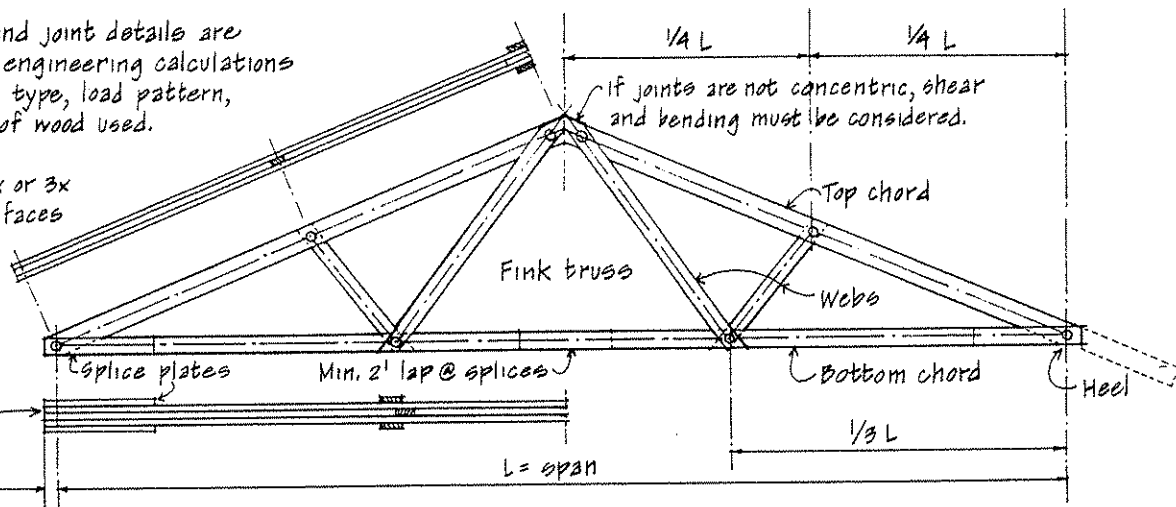
WOOD TRUSSES

Member sizes and joint details are determined by engineering calculations based on truss type, load pattern, span, and type of wood used.

Members are 2x or 3x material; wide faces offer more area for fastenings.

Trusses usually do not exceed 5 members in thickness

5 1/2" min.

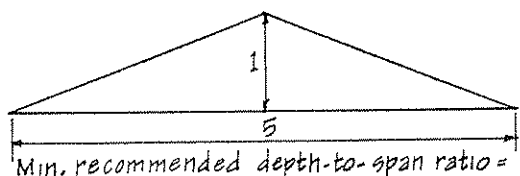
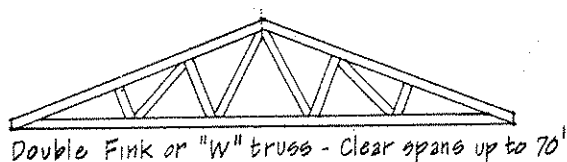


HEEL JOINT

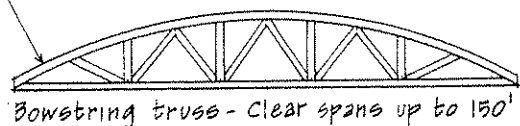
In contrast to monoplanar trussed rafters, heavier wood trusses can be made up of multiple members which are joined at the panel points with split-ring connectors. These wood trusses are capable of carrying greater loads than trussed rafters and are spaced further apart. When spanned simply with wood plank sheathing, the trusses can be spaced up to 8' or more, depending on the sheathing thickness. When purlins are used to frame between the trusses, the truss spacing may be increased up to 20'.

Vertical sway bracing between the top and bottom chords of adjacent trusses

Sheathing
Purlins @ panel points



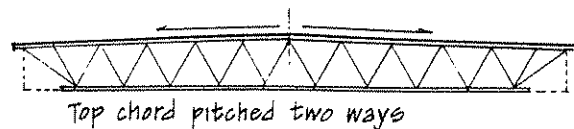
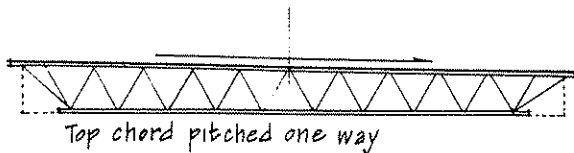
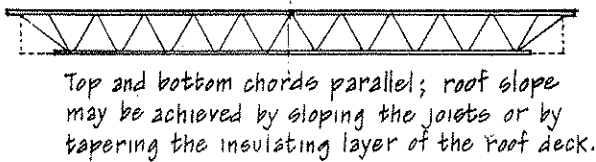
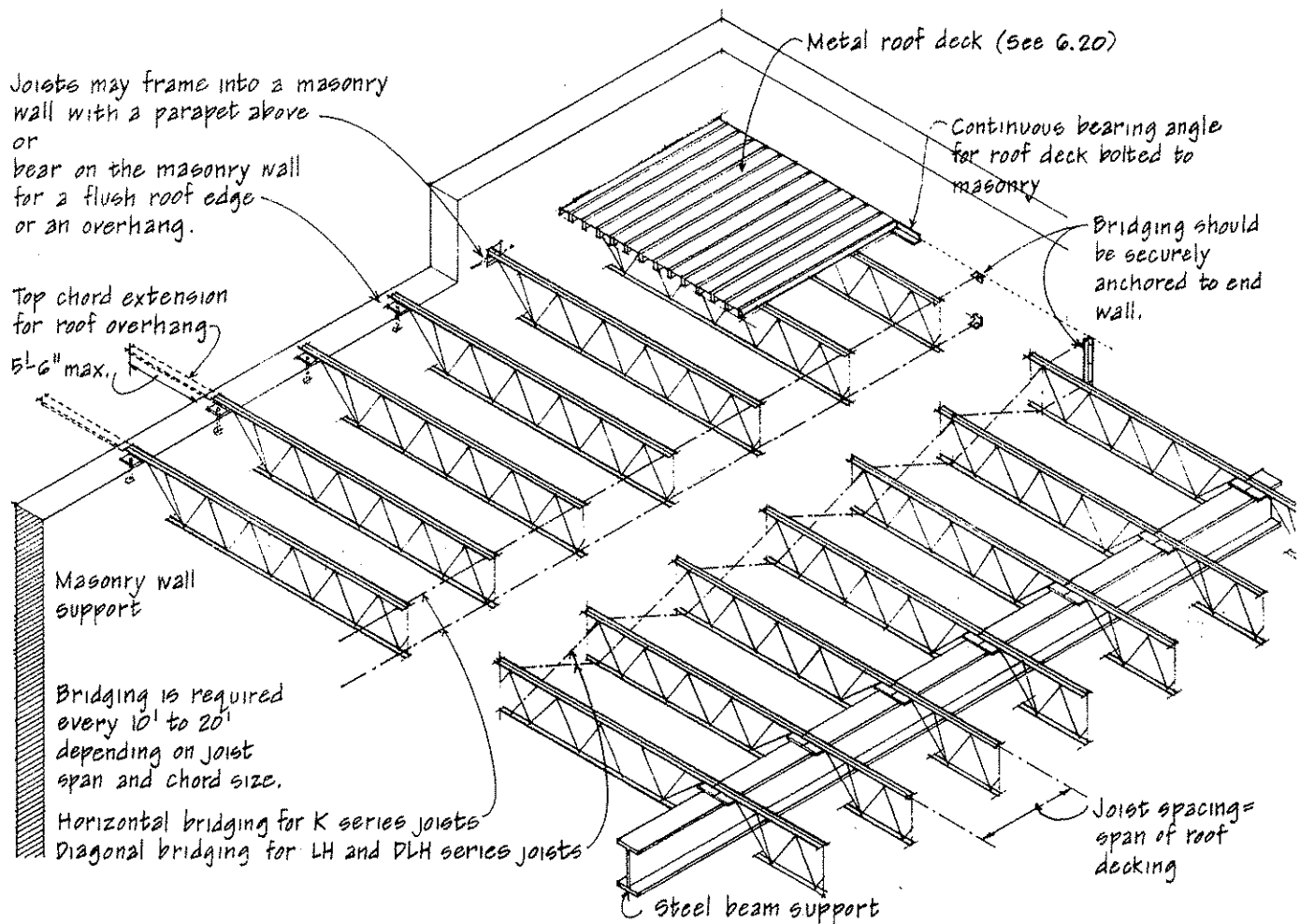
For bowstring trusses, radius of top chord = span



Knee bracing should connect to top or bottom chord @ a panel point.

Horizontal cross-bracing may be required in the plane of the top or bottom chord if the diaphragm action of the roof framing is not adequate for end-wall forces.

4.18 OPEN WEB JOIST ROOF SYSTEM



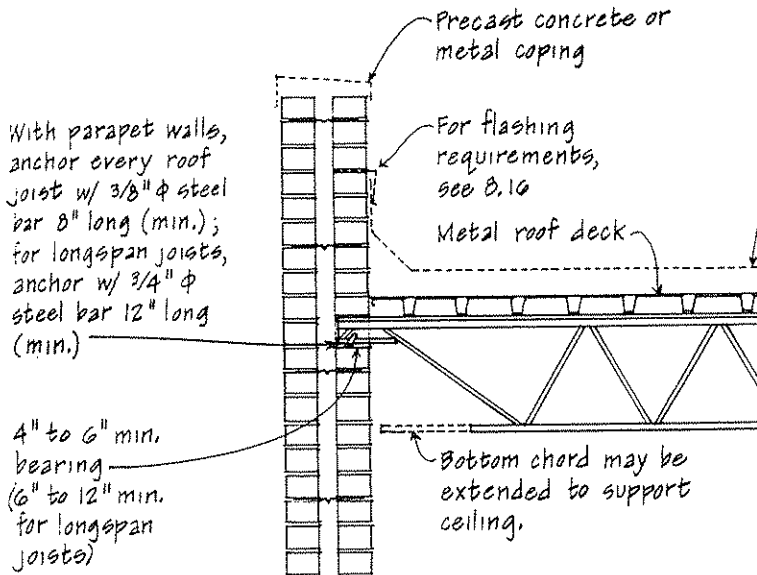
Longspan LH and DLH joists are available with single or double pitch top chords. Standard slope is $\frac{1}{8}$ " per foot.

The roof system utilizing open web steel joists is similar in layout and construction to the steel joist floor system. See 4.24.

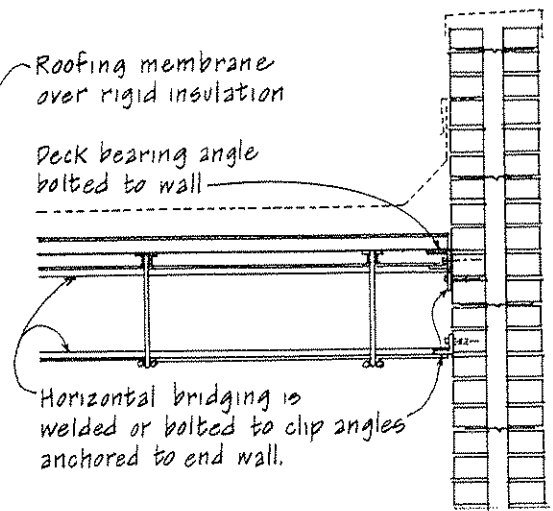
For joist sizes and allowable spans and loads, refer to the table on 4.25.

To resist potential wind uplift forces, every joist must be securely anchored to its supporting structure. In addition, the roof deck should be secured to all supports with puddle welds or mechanical fasteners. See 4.20 for metal roof decks.

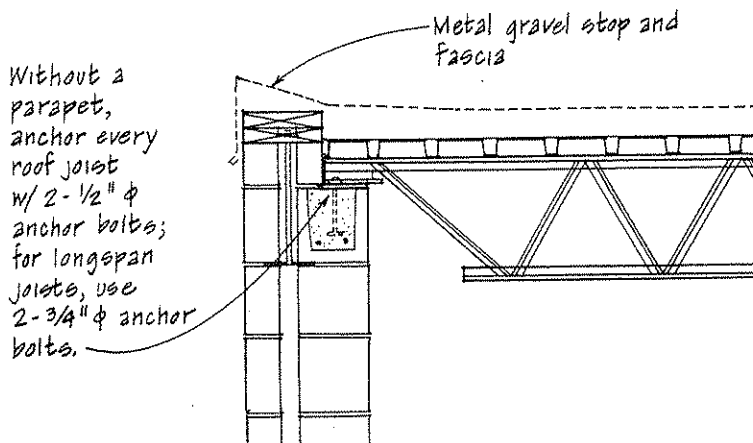
OPEN WEB STEEL JOISTS: SUPPORT CONDITIONS @ ROOF



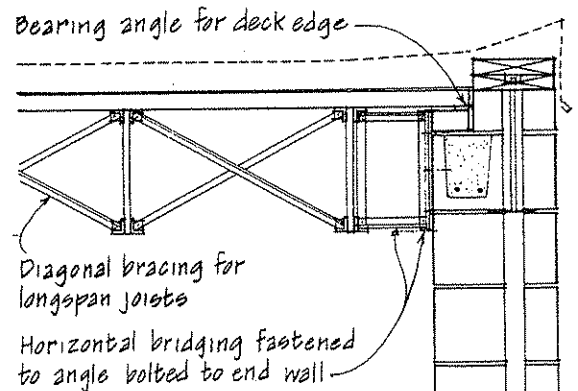
PARAPET: BEARING WALL



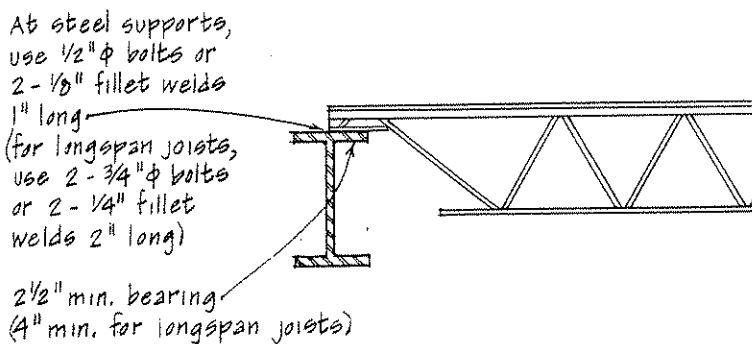
END WALL



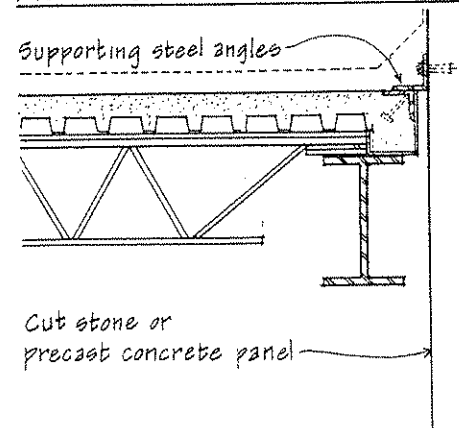
FLUSH EDGE: BEARING WALL



END WALL

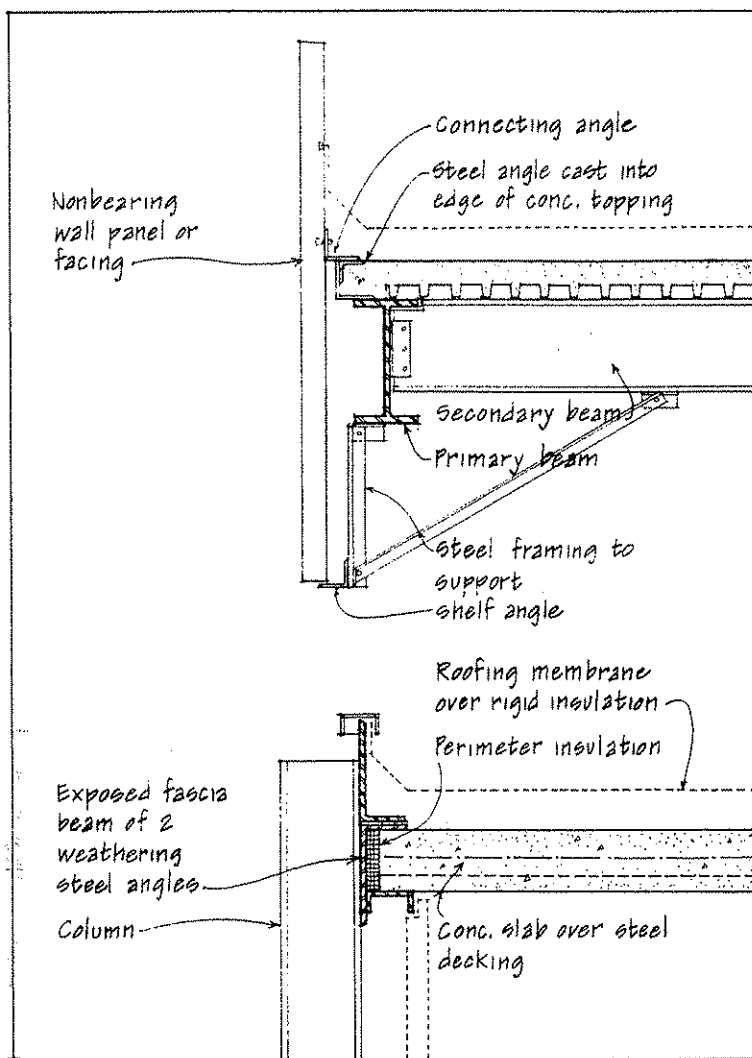


STRUCTURAL STEEL FRAME



PARAPET WALL

§.20 STRUCTURAL STEEL ROOF FRAMING



Roofs are framed with structural steel similar to the way steel floors are framed. See 4.20-4.23.

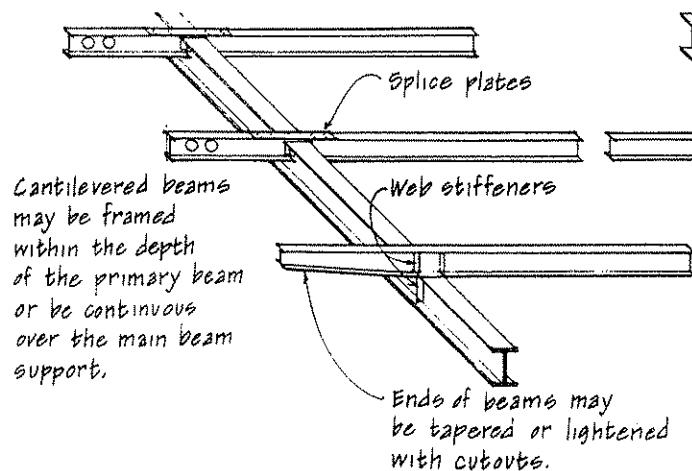
The primary and secondary roof beams may support a metal roof deck or a reinforced sitccast or precast concrete slab.

At the roof edge, a spandrel wall unit is supported either by the steel edge beam or the concrete roof slab. The wall assembly may extend up to form a curb or, if required, a parapet.

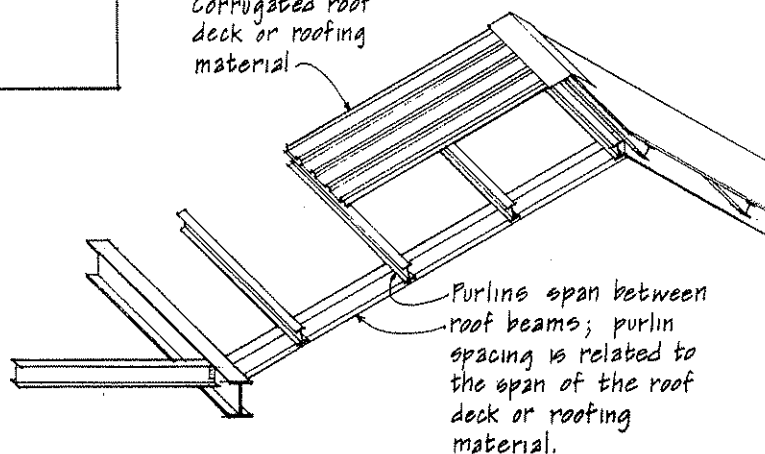
Thermal insulation may be provided with a lightweight insulating concrete fill or rigid insulating boards.

Roof overhangs may be achieved by cantilevering the secondary roof beams or recessing the exterior wall construction. Corrugated metal decking is also capable of limited cantilevers beyond its support.

Structural steel can also be used to frame sloping roofs.



Corrugated roof deck or roofing material



METAL ROOF DECKING

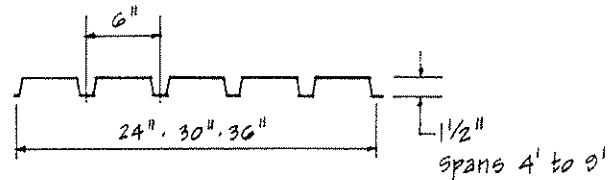
G.21

Corrugated metal roof decking may span across open web steel joists or more widely spaced steel beams. The decking panels are puddle welded or mechanically fastened to the supporting steel. Side laps between panels are fastened with screws or welds. If the deck is to serve as a diaphragm, its perimeter must be welded to steel supports.

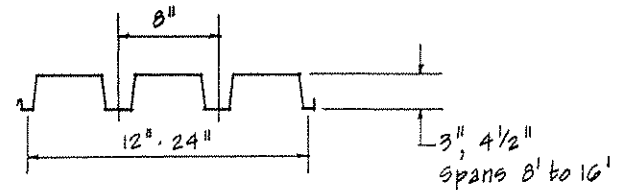
Metal roof decking may have a sitecast concrete topping or be covered with rigid board insulation before the application of the roofing membrane. To provide maximum surface area for the effective adhesion of rigid insulation, the top flange should be wide and flat. If the decking has stiffening grooves, the insulation layer may have to be mechanically fastened.

Metal decking has low-vapor permeance but, because of the many discontinuities between the panels, it is not airtight. If an air barrier is required to prevent the migration of moisture into the roofing assembly, a concrete topping can be used. When lightweight insulating concrete fill is used, the decking may have perforated vents for the release of latent moisture and vapor pressure.

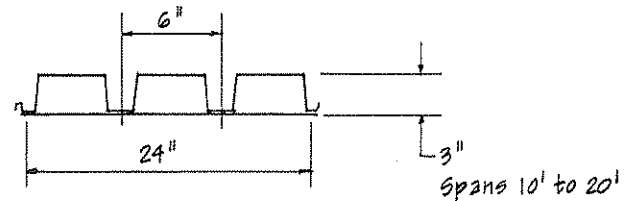
Acoustic roof decks have a filler of glass fiber or other acoustic insulating material.



RIBBED ROOF DECKING



RIBBED ROOF DECK

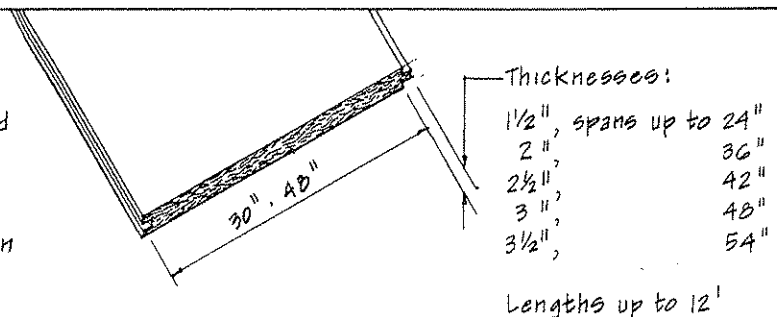


CELLULAR ROOF DECK

* Decking profiles vary with the manufacturer. Consult manufacturer for available profiles, lengths, gauges, allowable spans, and details for installation.

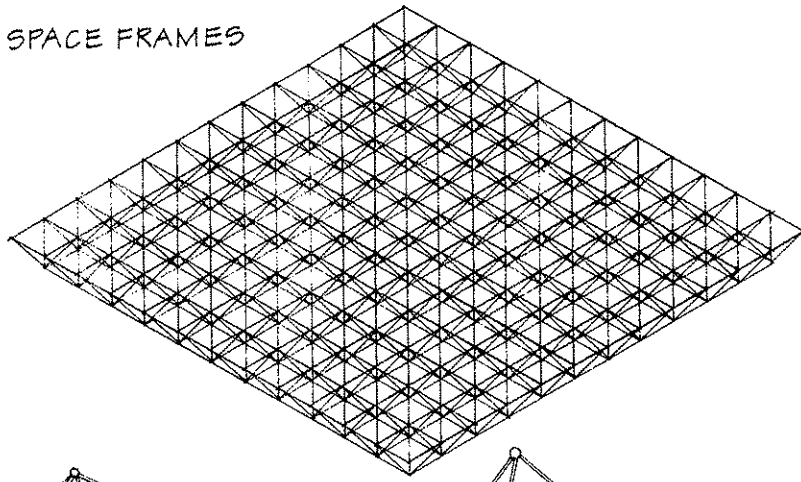
CEMENTITIOUS ROOF PLANK

Cementitious roof panels consist of wood fibers which are chemically processed and bonded under pressure with portland cement. These structural planks can be used to span wood or steel roof framing. They have thermal and acoustic insulation value and may be used in fire-resistant construction. They can serve as roof sheathing or as permanent formwork for a concrete slab and their undersides may be left exposed as a finish ceiling.

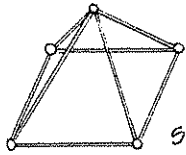


STEEL TRUSSES

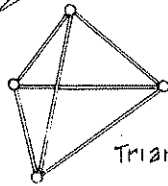
SPACE FRAMES



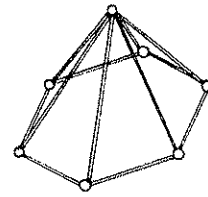
A space frame is a three-dimensional truss whose linear members form a series of triangulated polyhedrons. It can be seen as a plane of constant depth which is capable of fairly long spans. Because its members lack a hierarchy of size and pattern, the frame projects an image of nondirectional texture. Three of the many patterns available are illustrated below.



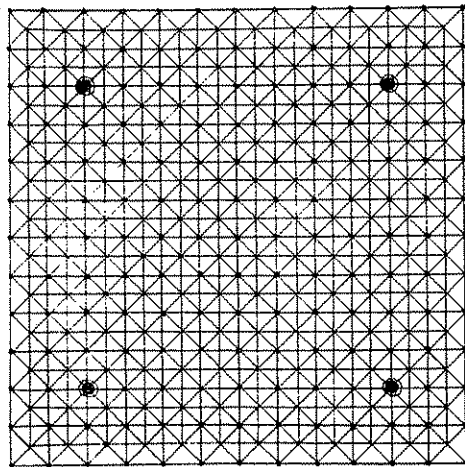
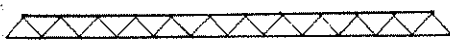
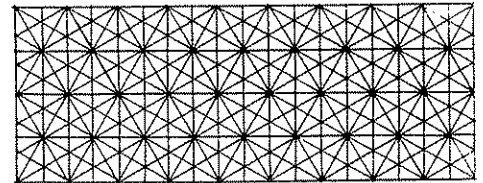
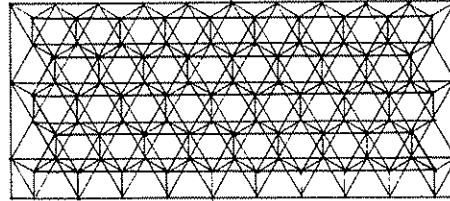
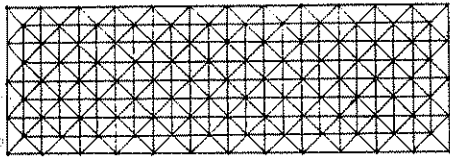
Square grid



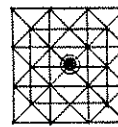
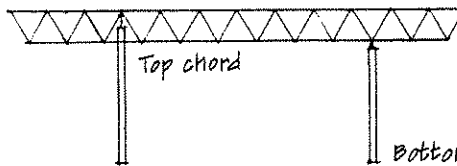
Triangular grid



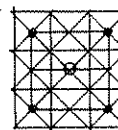
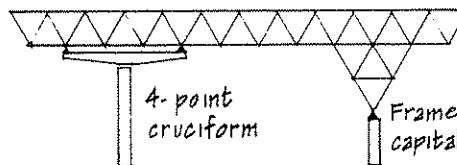
Hexagonal grid



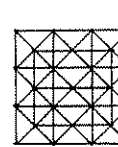
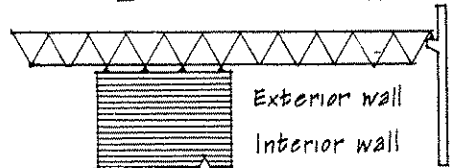
Because of its three-dimensional trusswork, a space frame may have various modular configurations and randomly spaced supports. The most efficient means of support, however, are columns which are equally spaced in two directions.



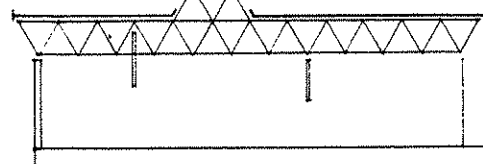
A space frame's supports are always at a panel point.



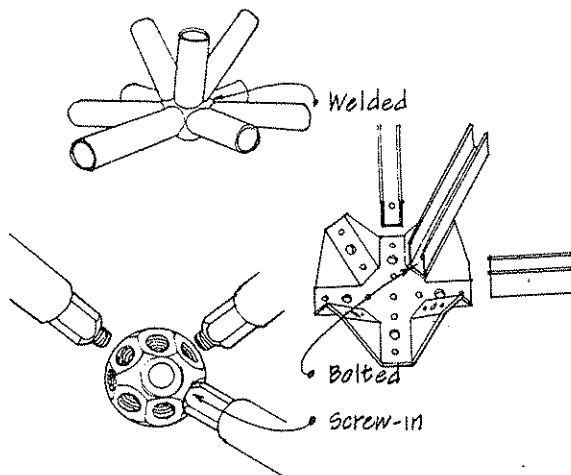
A column may disperse its support points.



A bearing wall distributes its support points along a line.



Roof and partition connections are also made at panel points.



Chord members of space frames may be structural pipe, tubing, channel, tee, or W-shapes.

The complex connection between the large number of members may be welded, bolted, or of the screw-in type. Consult manufacturer for details, module size, and allowable spans.

Wood panel sheathing, metal decking, or cementitious planks (Slope or camber frame for drainage)

Typical modules: 4', 5', 8', 12'

Depth-to-span ratio for roofs:
1:18 if column-supported
1:20 if wall-supported

Span: 6 to 36 modules

Cantilevers: 15% to 30% of span

Roof sheathing or corrugated roofing

Channel or W shape purlins
If not at a panel point,
purlins subject top
chord to local bending.

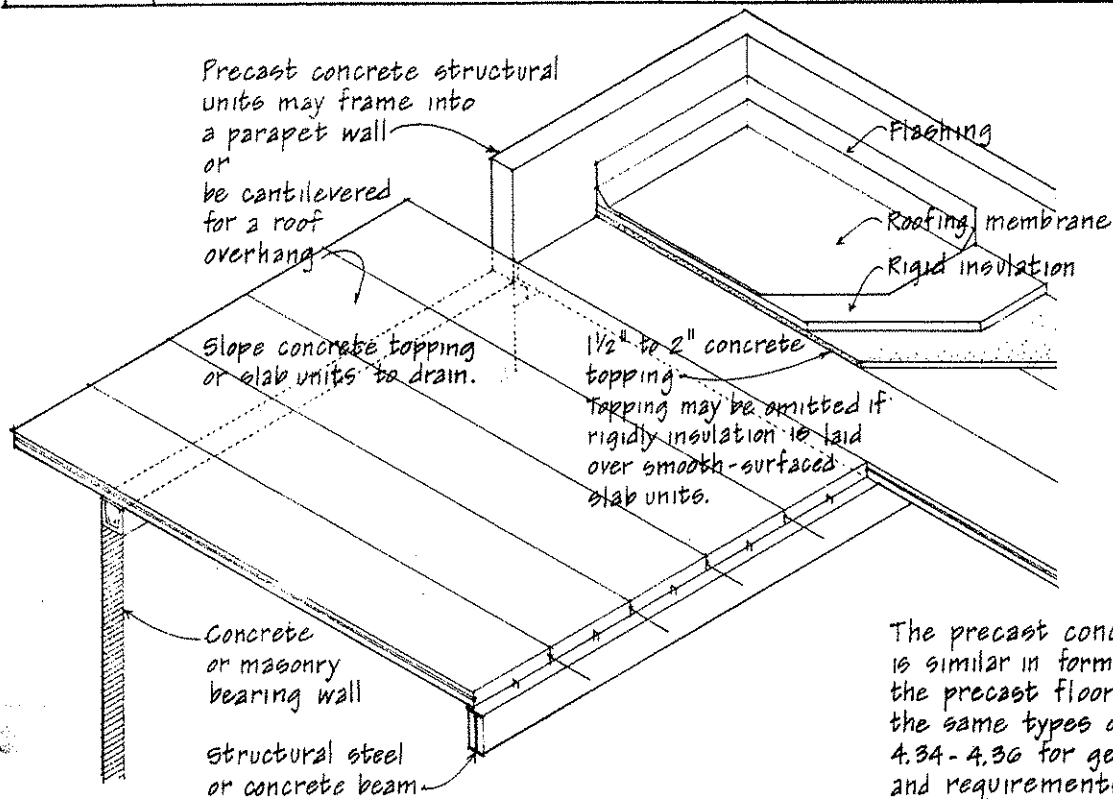
Column support

Members are bolted
or welded with a gusset
plate connector

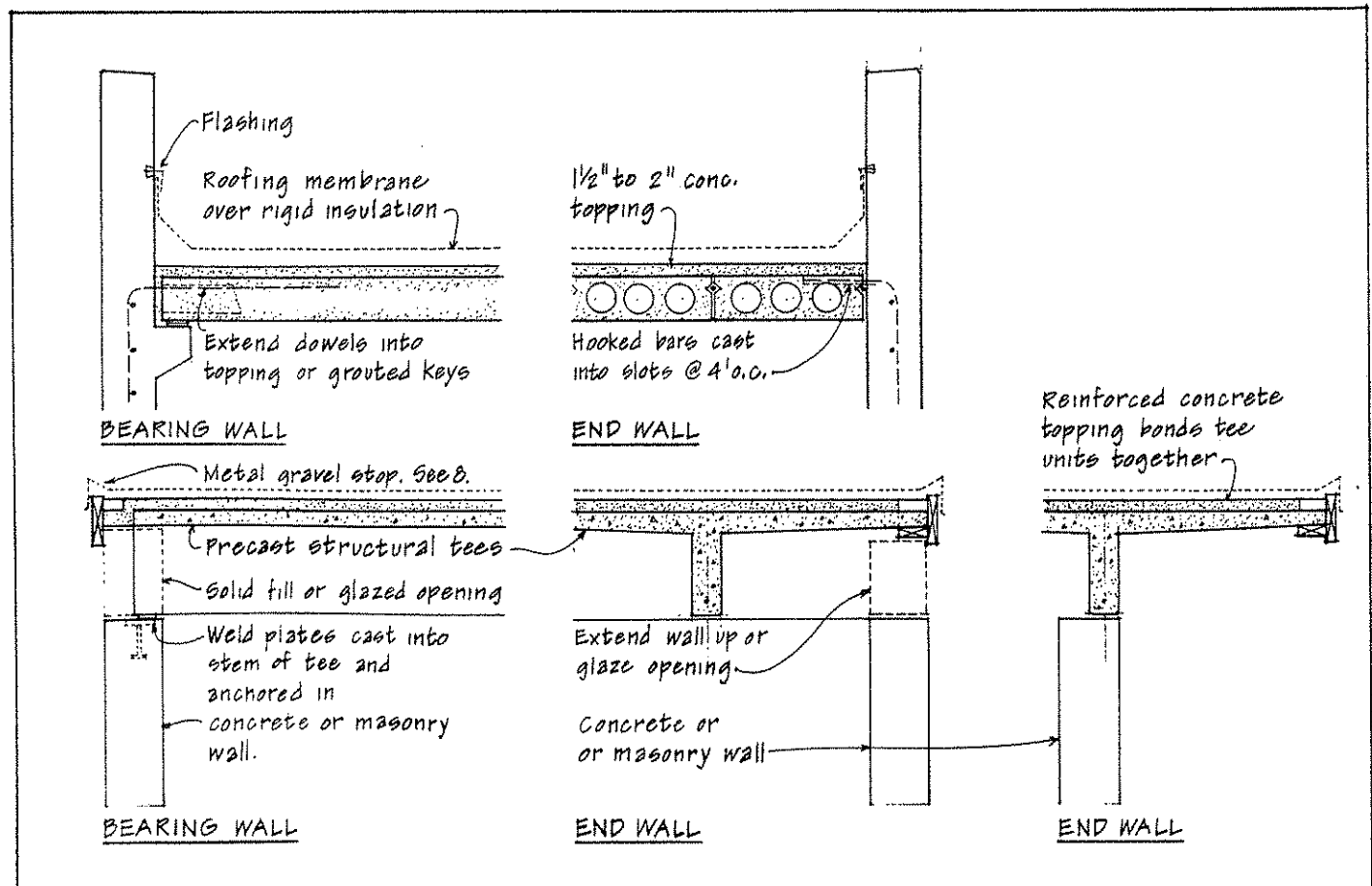
Illustrated here is a Belgian truss.
See G.16 - G.17 for other truss
configurations. It is generally
best to use truss type in which
the longer web members are
loaded in tension.

Plane roof trusses may be fabricated with
structural steel angle and tee shapes. Because of
the members' slenderness, connections usually
require the use of gusset plates.

PLANE STEEL TRUSSES



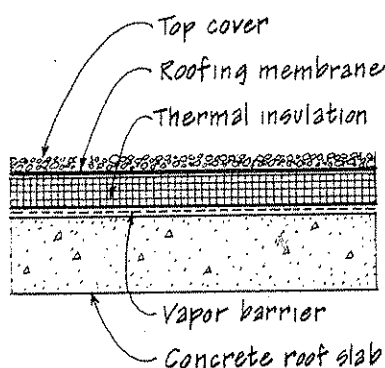
The precast concrete roof system is similar in form and construction to the precast floor system and utilizes the same types of slab units. See 4.34 - 4.36 for general conditions and requirements.



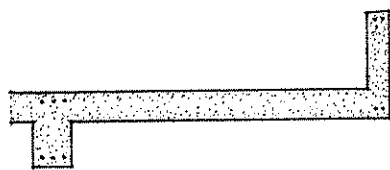
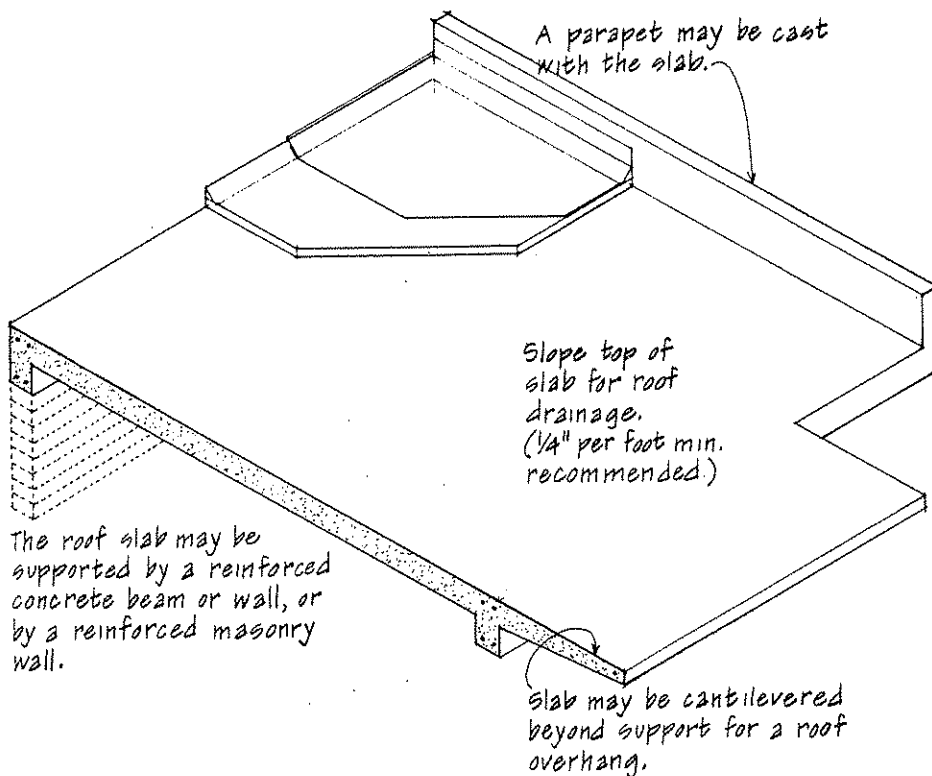
REINFORCED CONCRETE ROOF SLABS

Reinforced concrete roof slabs are formed and sitecast in the same way as the concrete floor systems illustrated on 4.32 and 4.33.

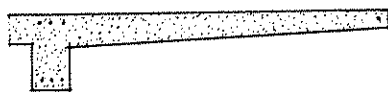
Roof slabs are normally roofed with a membrane type of roofing as shown in the cross-section. See 8.2-8.5 for details.



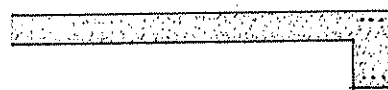
The edge of a concrete roof slab may be treated in three different ways.



An upturned edge beam can form a parapet wall.

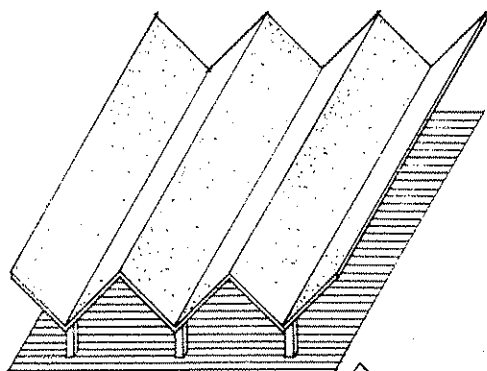


The slab can be cantilevered beyond its support to form an overhang.

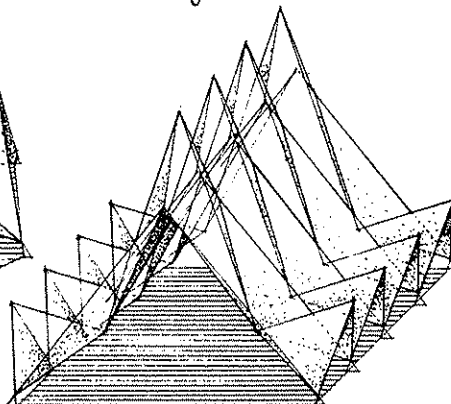
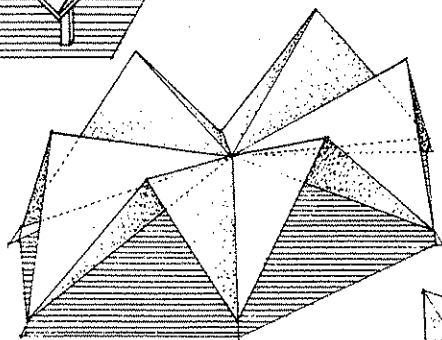


An edge or spandrel beam can support a nonbearing wall.

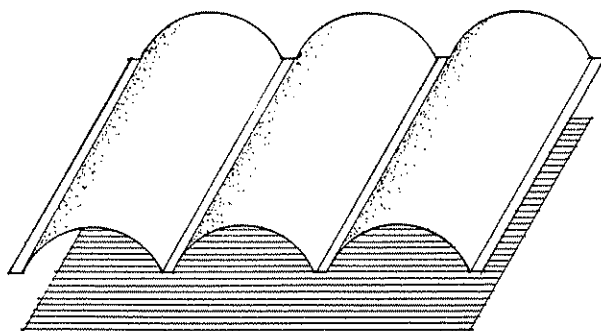
ROOF EDGE CONDITIONS



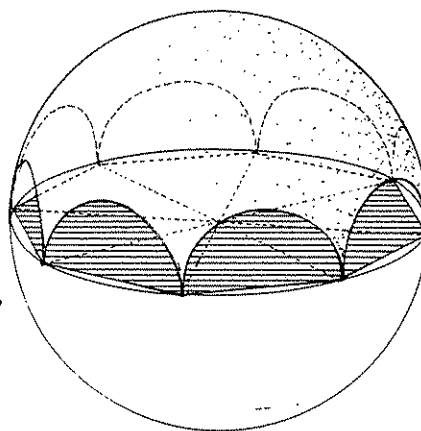
Although beyond the scope of this book, illustrated on this page are examples of surface-active structural systems which are capable of spanning long distances. Concrete is well-suited for the construction of these systems since it can be reinforced and formed into the structural shapes with the required continuity of surface.



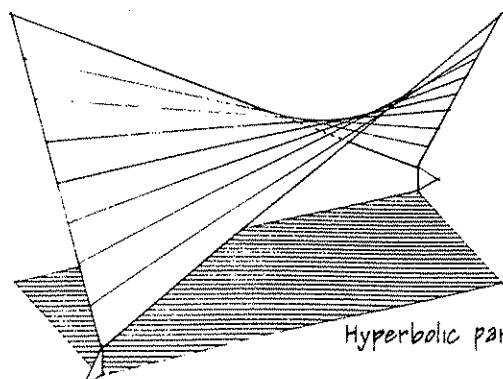
FOLDED PLATE STRUCTURES



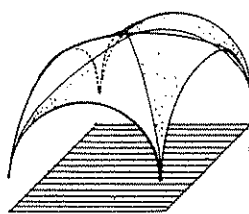
Cylindrical vaults



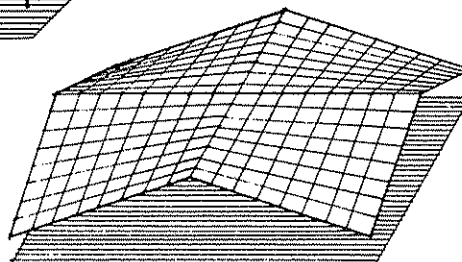
Domes



Hyperbolic paraboloids



Intersecting vaults



SHELL STRUCTURES

DOORS & WINDOWS

Doors and doorways provide access into a building's interior from the exterior and passage between interior spaces. Exterior doors should provide weathertight seals when closed and maintain the approximate insulation value of the building's exterior walls. At the same time, doorways should be large enough to move through easily and accommodate the moving of furnishings and equipment. Ease of operation, requirements for privacy and security, and any need for light, ventilation, and view should also be considered in a door's performance.

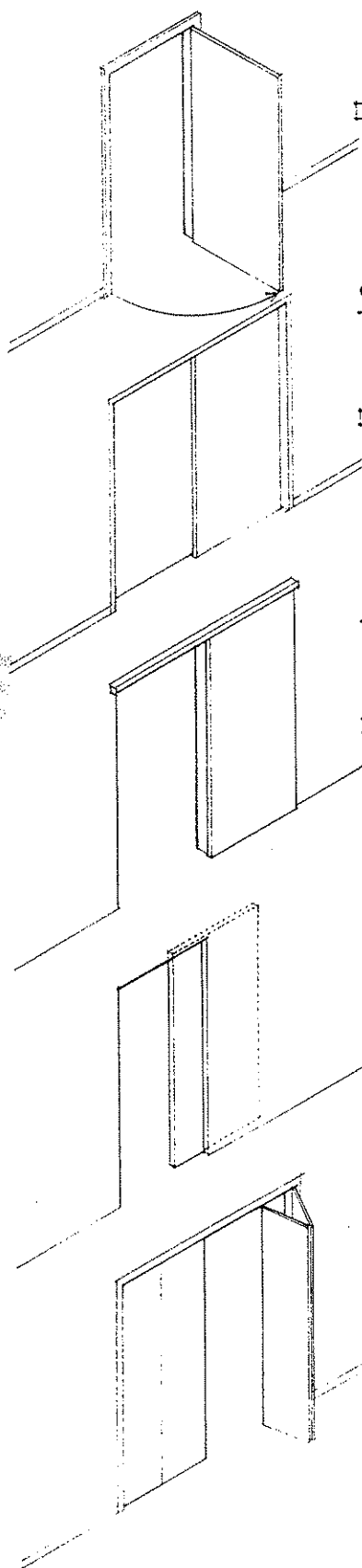
Interior doors provide for passage, visual privacy, and sound control between interior spaces. Doors into closets and storage spaces are primarily for visual screening although ventilation may also be a requirement.

There are many types and sizes of windows, the choice of which affects not only the physical appearance of a building, but also the natural lighting, ventilation, view potential, and spatial quality of the building's interior. As with exterior doors, windows should provide a weathertight seal when closed, have insulation value, and resist the formation of condensation on their interior surfaces.

Since door and window units are normally factory-built, manufacturers may have standard sizes and corresponding rough-opening requirements for the various door and window types. The size and location of doors and windows should be carefully planned so that adequate rough openings with properly sized lintels can be built into the building's wall systems.

From an exterior point of view, doors and windows are important compositional elements in a building's facades. The manner in which they break up a building's wall surfaces affects the massing, visual weight, scale, and articulation of the building form.

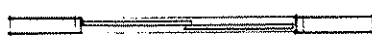
7.2 DOOR TYPES BY OPERATION



• SWINGING

- Normally hinged on side jamb; may also be pivoted from head jamb and threshold.
- Most convenient operation for entry and passage.
- Requires space around doorway for door swing; check clearance required.
- Most effective door type for thermal and acoustic insulation, and for weather resistance.

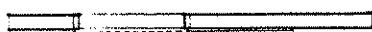
Exterior and interior use



- Provides an opening in a minimum amount of space but sacrifices acoustic insulation.
- Offers access only to 50% of doorway.
- Doors slide on overhead track and along guides or a track on the floor.
- Used on exterior as sliding glass doors.
- Used in interior primarily for visual screening.

• BYPASS SLIDING

Exterior and interior use



- Similar to above but provides 100% opening of doorway.
- Door is surface-hung on an exposed overhead track.

• SURFACE SLIDING

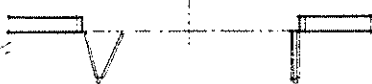
Exterior and interior use



- Provides 100% opening of doorway by sliding into a recess within the width of the wall.
- Doorway has a finished appearance when fully open.
- Used where a normal door swing would interfere with the use of a space.

• POCKET SLIDING

Interior use



- Provides nearly 100% opening of doorway.
- Uses an overhead track and hinged door panels.
- Used primarily as a visual screen to enclose closet and storage spaces.

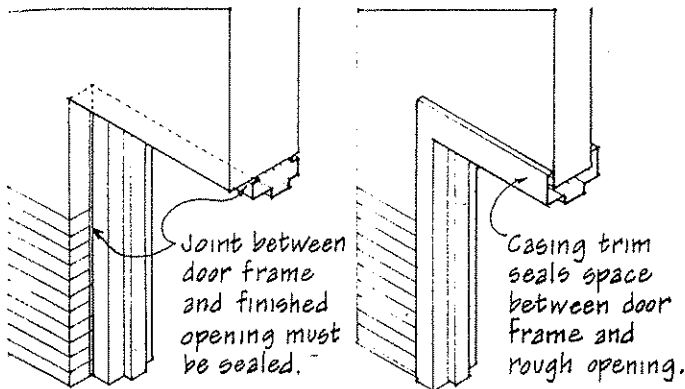
• SIDE-HINGED FOLDING

Interior use

- See 7.13 for revolving doors.

BASIC ELEMENTS OF A DOORWAY

7.5



① DOOR FRAME

The door frame detail determines the appearance of the doorway, whether the frame is set within a finished opening or wrapped around a rough opening.

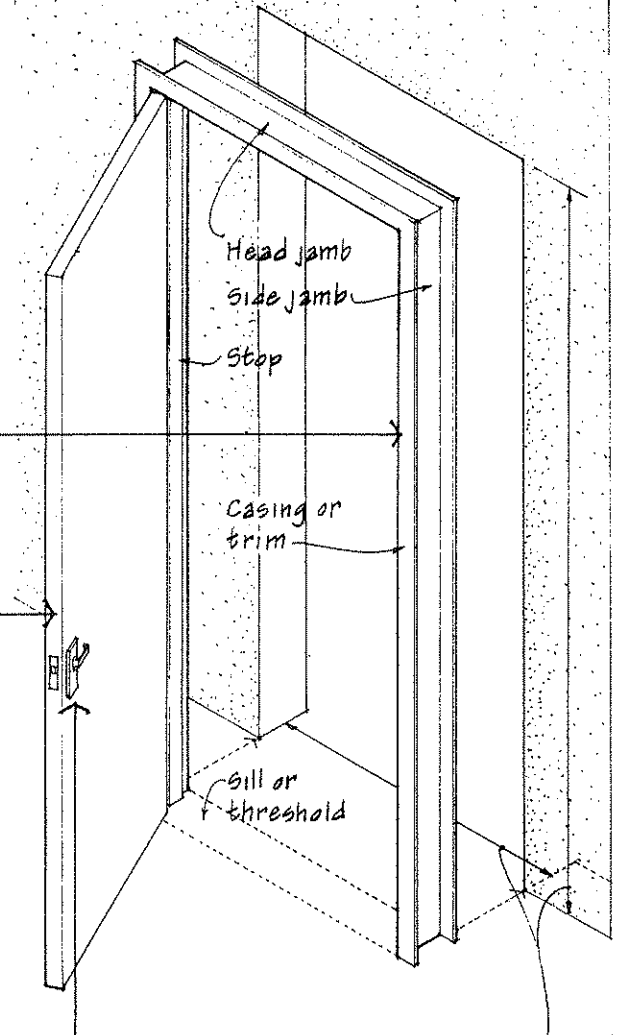
② DOOR

The type, size, and location of a door is related to:

- Physical access requirements
- Effect on the pattern of movement within and between spaces
- Anticipated frequency of use
- Requirements for weathertightness, thermal insulation, and durability
- Light, view, and ventilation requirements
- Acoustic privacy desired
- Code requirements for fire-resistance and emergency egress
- Visual appearance desired.

③ DOOR HARDWARE

This includes the hardware required for the operation of a door, such as hinges, locksets, and closers.



The rough or finish opening required for a door depends on the door type, how it is framed, and the wall's material, thickness, and construction.



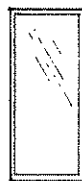
Flush



Panel



French



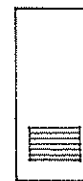
Glass



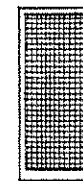
Sash



Louver



Louver



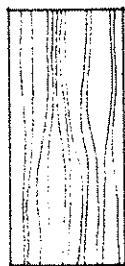
Screen



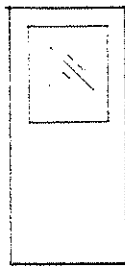
Dutch

DOOR TYPES by DESIGN

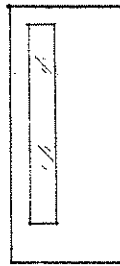
7.4 WOOD FLUSH DOORS



Flush

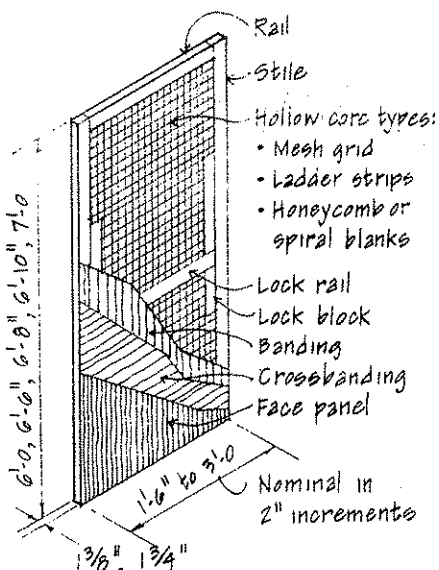


With glass inserts



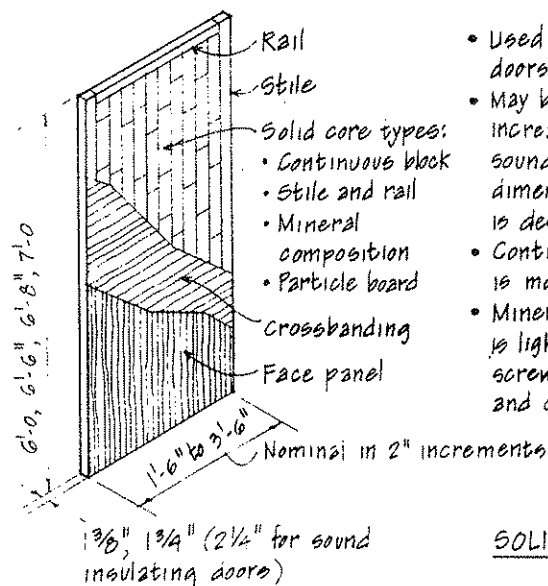
With louvered insert

- Openings should be less than 40% of door area and no closer than 5" to any edge.
- Height of openings in hollow core doors should be less than half the door height.



- Primarily for interior use
- May be used for exterior doors if bonded with waterproof adhesives
- Light in weight
- Has little inherent thermal or acoustic insulation value
- Susceptible to warping

HOLLOW CORE DOORS



- Used primarily as exterior doors
- May be used wherever increased fire resistance, sound insulation, or dimensional stability is desired
- Continuous block core is most economical.
- Mineral composition core is lightest but has low screw holding strength and cutouts are difficult.

SOLID CORE DOORS

GRADES AND FINISHES

- Hardwood veneer grades:
 - Premium: for natural, transparent finishes
 - Good: for transparent or paint finishes
 - Sound: for paint finishes - requires 2 coats
- Plastic: High pressure plastic laminate bonded to face
- Hardboard: Hardboard face panels for paint finishes.

Doors may be factory finished partially with a seal coat or completely including prefitting and premachining for hinges and locksets.

SPECIAL DOORS

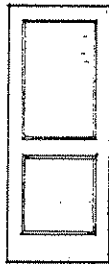
- Fire-rated doors:
 - Usually have mineral composition cores
 - B-label: 1-hour and 1 1/2 hour UL approved rating
 - C-label: 3/4-hour UL rating
- Acoustic (sound insulating) doors: Core includes a void or damping compound. Special stops, gaskets, and thresholds are also required.
- Lead-lined and copper-shielded doors are also available.

WOOD RAIL AND STILE DOORS

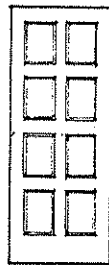
7.5



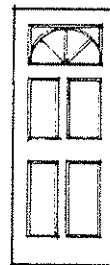
Panel



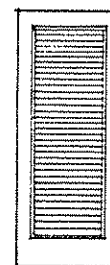
Panel



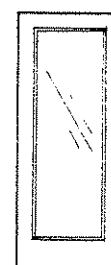
Panel



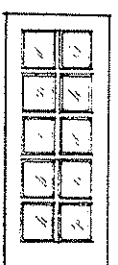
With sash



Louvered



French (casement)

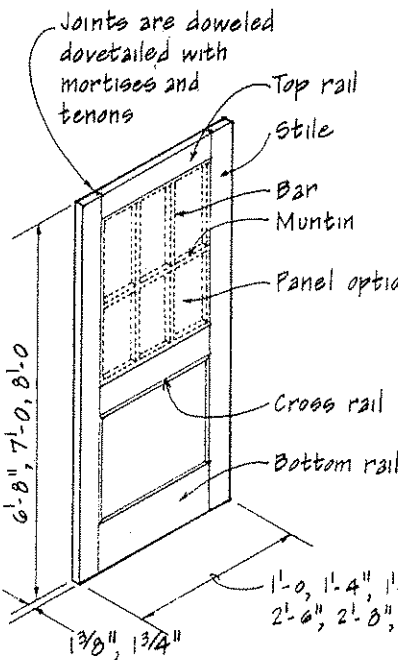


With divided lights

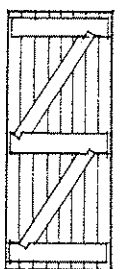
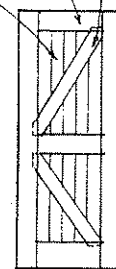
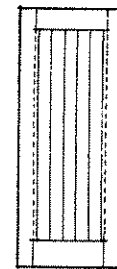
Panel doors consist of a framework of vertical (stile) and horizontal (rail) members which hold solid wood or plywood panels, glass lights, or louvers in place. The stiles and rails may be solid softwood or veneered hardwood.

GRADES AND FINISHES

- Premium (select) grade: for natural clear or stained finishes
- Standard grade: for paint finishes only



Diagonal bracing
Ledger
Sheathing



Batten doors

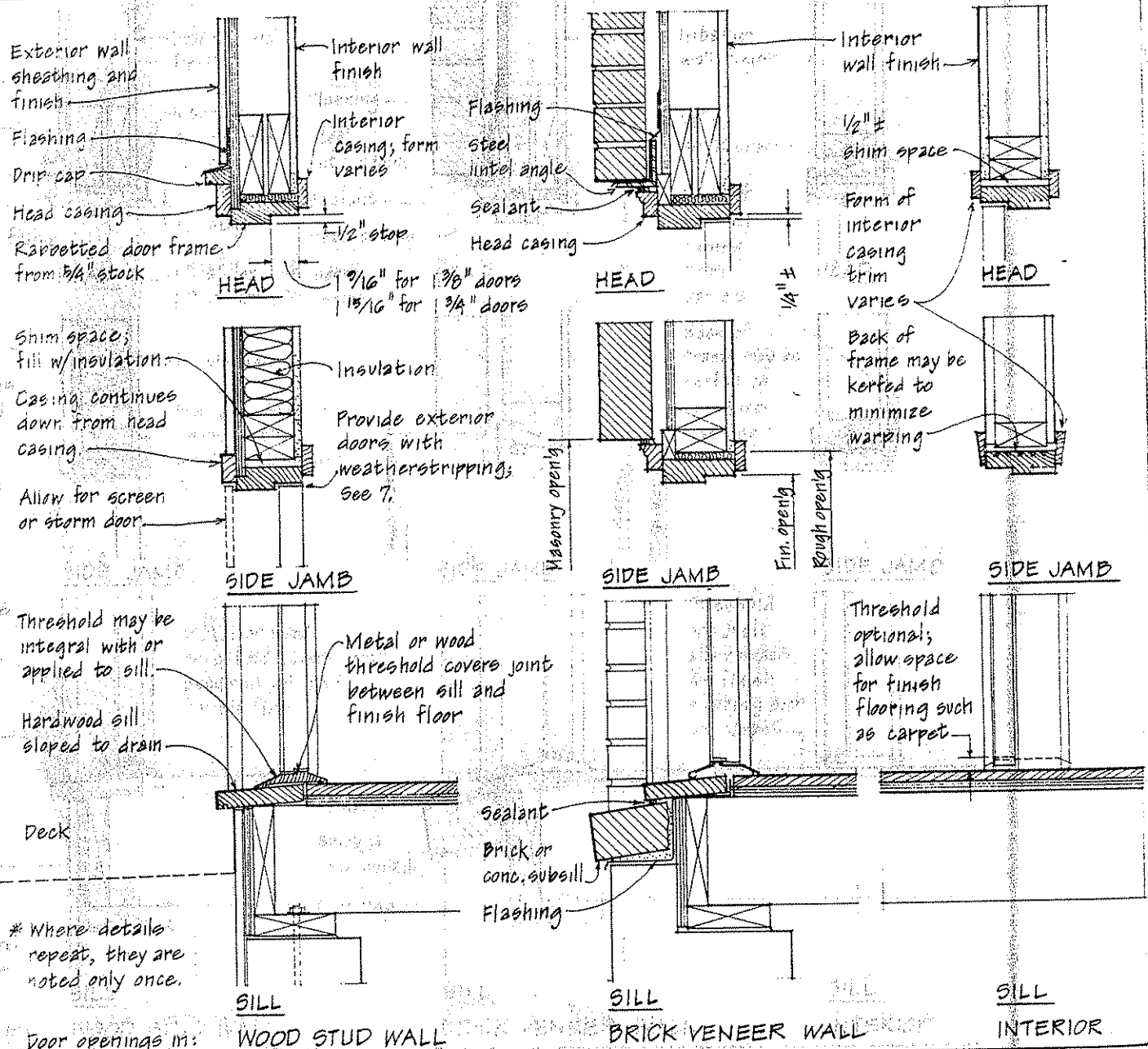
Batten doors consist of vertical boards (sheathing) nailed at right angles to cross strips (ledgers). Diagonal bracing is nailed between and notched into the ledgers.

- Used primarily for economy in rough construction
- Usually site fabricated
- Tongue-and-groove sheathing is recommended for weathertightness.
- Subject to expansion and contraction with changes in moisture content.

$$1 \frac{3}{8}$$

$$1 \frac{1}{8} \cdot 2 \frac{1}{8} \cdot 2 \frac{1}{8}$$

7.6 WOOD DOOR FRAMES



Wall construction

Shim space (1/2" ±) allows door frame to be plumbed.

Casing trim seals space between door frame and wall; exterior joints may require sealing.

Rabbetted door frame; interior frames may have applied stops.

Head and side jamb conditions are usually similar so that the casing trim profile may be continuous around the doorway.

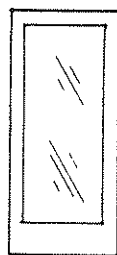
Cased openings may be used without doors and therefore have no stops.

HOLLOW METAL DOORS

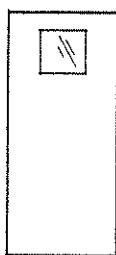
7.7



Flush



Glass



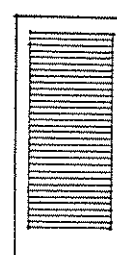
Vision



Narrow light



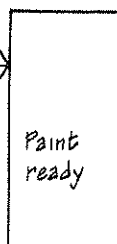
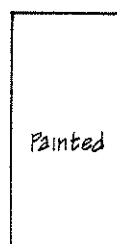
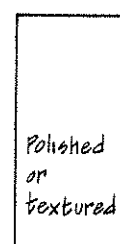
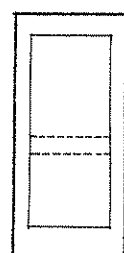
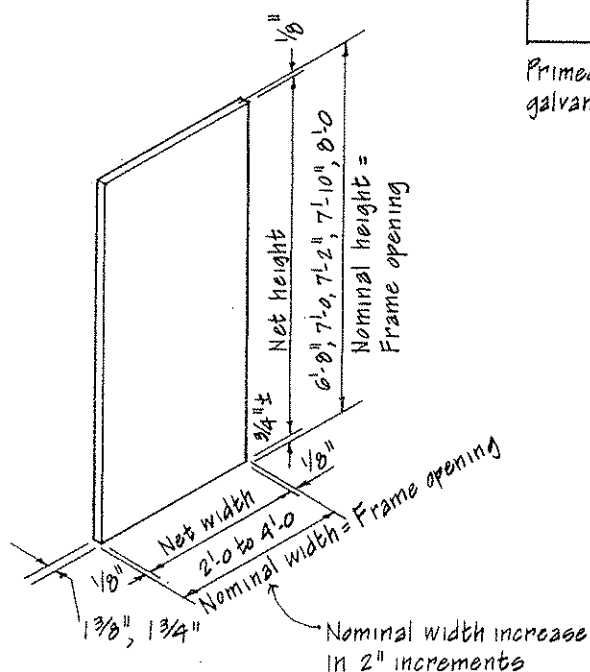
Louvered



Louvered

DOOR TYPES

DOOR FINISHES

Paint
ready
Primed and/or
galvanizedPainted
Baked
enamelVinyl clad
(applied)Polished
or
textured
Stainless steel
or aluminum

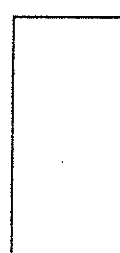
Rail and stile

Infill may be
flush or recessed
panel, glass,
or louvers



Rail panel

Exposed vertical
seams
Inverted channel
at top and
bottom



Flush

No visible seams
on face
Pan or enclosed
grid construction
Flush or recessed
at top and
bottom

DOOR CONSTRUCTION: 16 to 22 ga. metal

FIRE DOORS:

Fire door assemblies (door, frame, and hardware) are required to protect openings in fire-rated walls. See A.11.

UL label Rating

Glazing permitted *

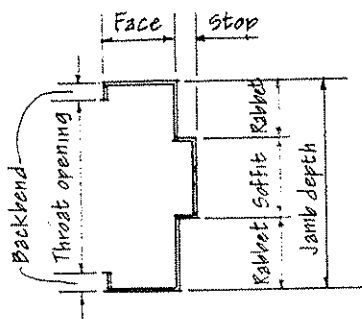
A	3 hour	No glass permitted
B	1 1/2 hour	100 sq.in. per leaf
C	3/4 hour	1200 sq.in. per leaf; 54" max. dimension
D	1 1/2 hour	No glass permitted
E	3/4 hour	720 sq.in. per leaf; 54" max. dimension

* 1/4" wire glass

General requirements

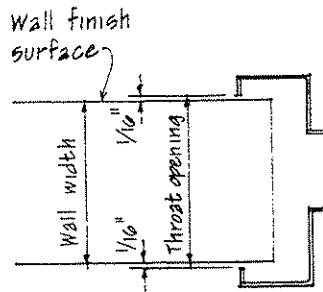
- Maximum door size: 4' x 10'
- Door frame and hardware must have a rating similar to that of door.
- Door must be self-latching and be equipped with closers.
- Louvers with fusible links are permitted for B and C label doors; max. area = 570 sq.in.
- No glass and louver combinations are permitted.

7.8 HOLLOW METAL FRAMES

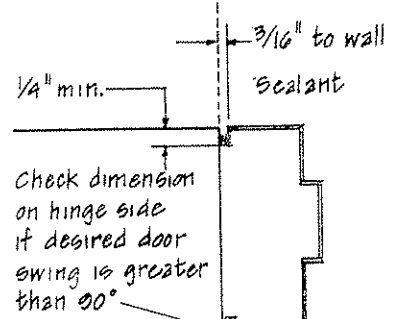


Frame profile may vary w/ manufacturer

STANDARD DOUBLE-RABBIT FRAME



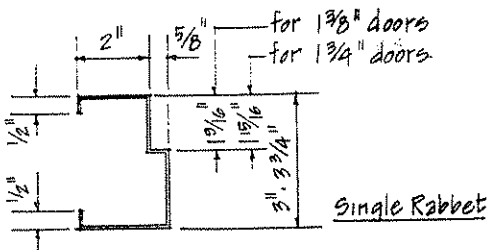
• Wrap Around Frame



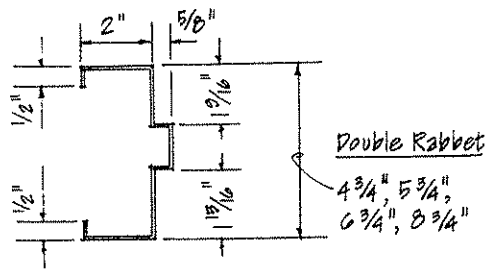
• Butte Frame

4" min. in area of door pull or knob

FRAME INSTALLATION CONDITIONS



Single Rabbit

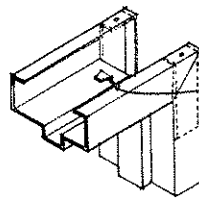


Double Rabbit

Standard gauges: 14-16-18

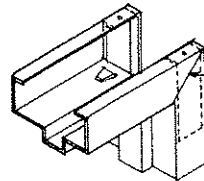
Standard finish: Factory-primed for paint

STANDARD SIZES



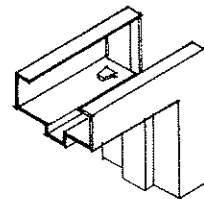
Corner reinforcement
Concealed tabs

① Knock-down Frame



Similar to above but joints are arc-welded.

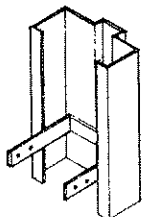
② Welded Assembly



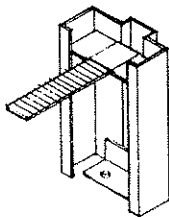
No miters or joints are visible.

③ Welded and ground smooth

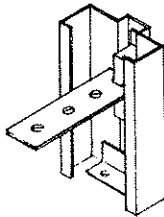
CORNER CONSTRUCTION



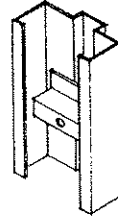
Wood stud anchor



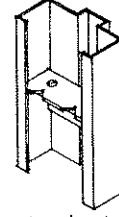
Loose T for masonry



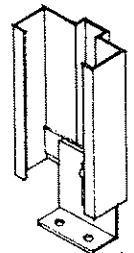
UL approved masonry anchor



Spacing bracket anchor for existing walls



Steel stud anchor

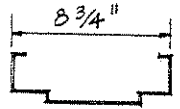
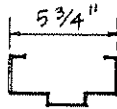


Adjustable floor clip

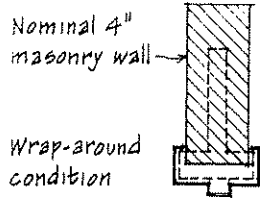
ANCHOR TYPES (Minimum of 3 required per jamb)

HOLLOW METAL FRAME INSTALLATIONS

7.9



FRAME SIZES

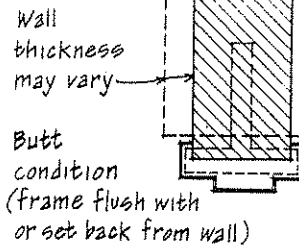
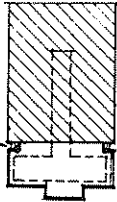


Nominal 4"
masonry wall

Wrap-around
condition

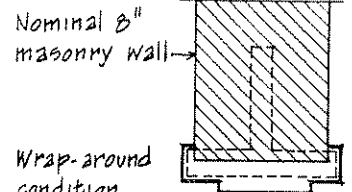
Sealant

Butt condition
for new or existg
openings



Wall
thickness
may vary

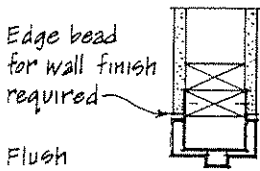
Butt
condition
(frame flush with
or set back from wall)



Nominal 8"
masonry wall

Wrap-around
condition

MASONRY WALL OPENINGS

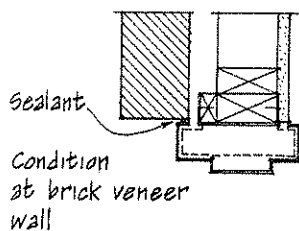
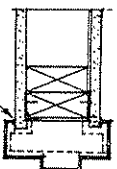


Edge bead
for wall finish
required

Flush
condition

Wall finish
continues into
throat opening

Wrap-around
condition

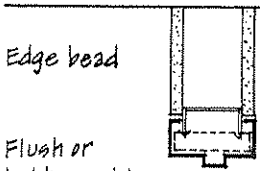


Sealant

Condition
at brick veneer
wall

Frames may be grouted full
with mortar or plaster as
used in wall for a more
secure and fire-resistant
installation

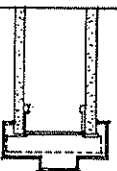
WOOD STUD WALL OPENINGS



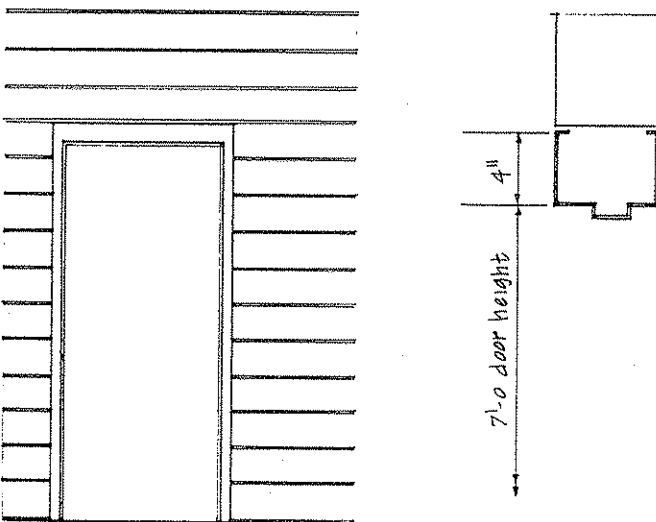
Edge bead

Flush or
butt condition

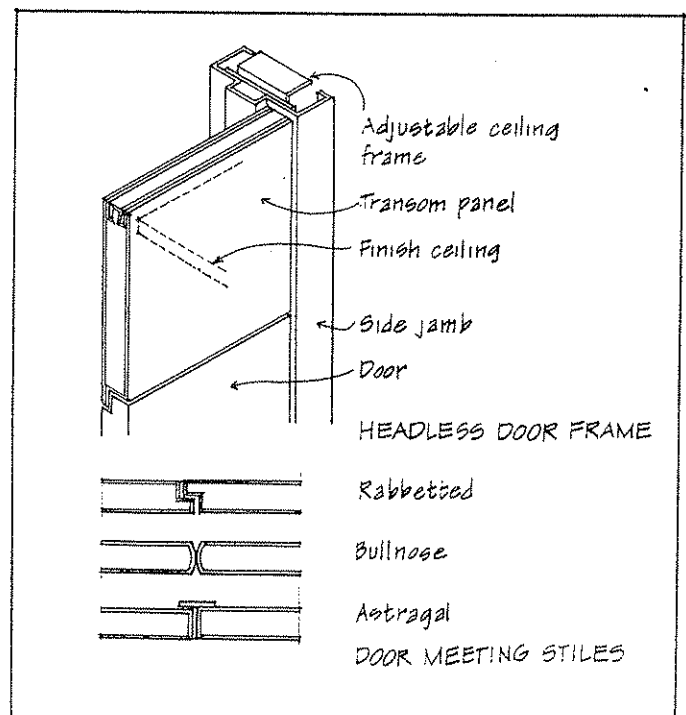
Wrap-around
condition



STEEL STUD WALL OPENING



A 4" head frame is available which can help the
door frame height fit modular masonry openings.



Adjustable ceiling frame

Transom panel

Finish ceiling

Side jamb

Door

HEADLESS DOOR FRAME

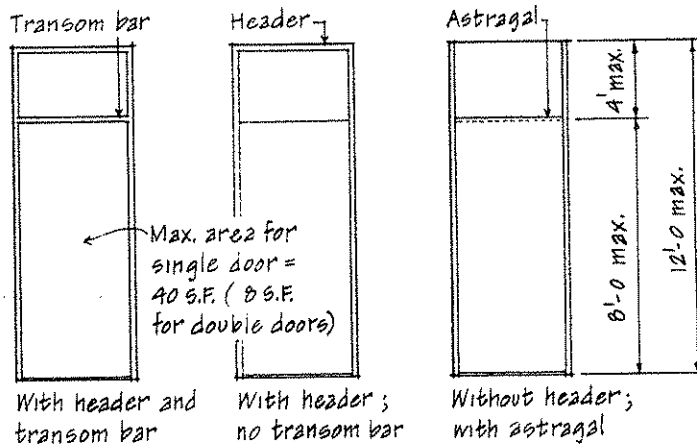
Rabbetted

Bullnose

Astragal

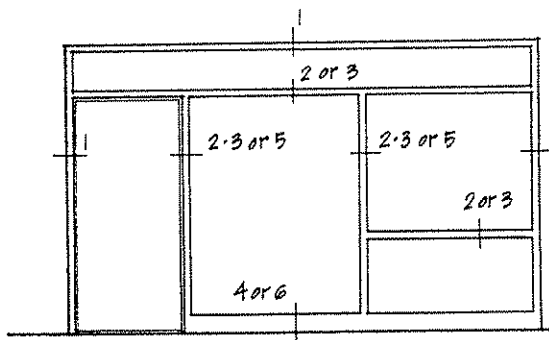
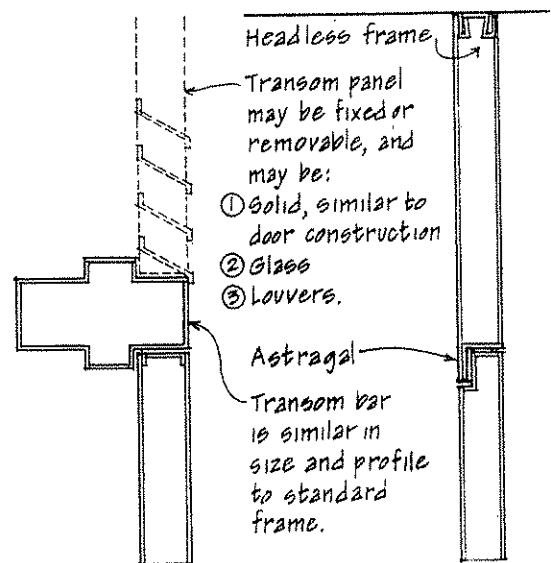
DOOR MEETING STILES

7.10 HOLLOW METAL FRAMES: TRANSOM PANELS AND STICK COMPONENTS



TRANSOM PANEL CONDITIONS

Transom panels continue the door plane up to the finish ceiling. They may have an A or B label fire-resistance rating.



The framing members are similar in size, profile, and finish to standard hollow metal door frames. They may be used to frame sidelights, borrowed lights, and transoms.

- Primarily a stick system which can be arranged in various ways.
- The types of fastenings, joints, and anchorages used vary with the system manufacturer.

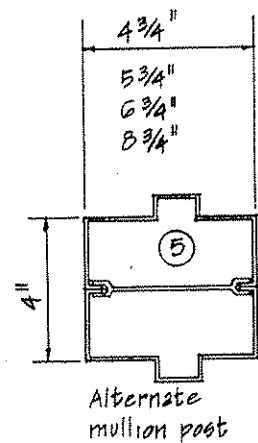
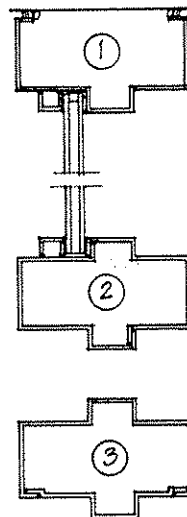
HOLLOW METAL FRAMES FOR WINDOW WALLS

HEAD
(Jambis similar)

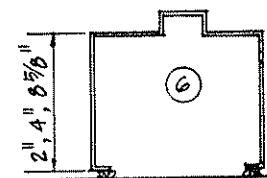
Applied stops for glass or insulated sandwich panels

MULLION
(Header bar)

SILL

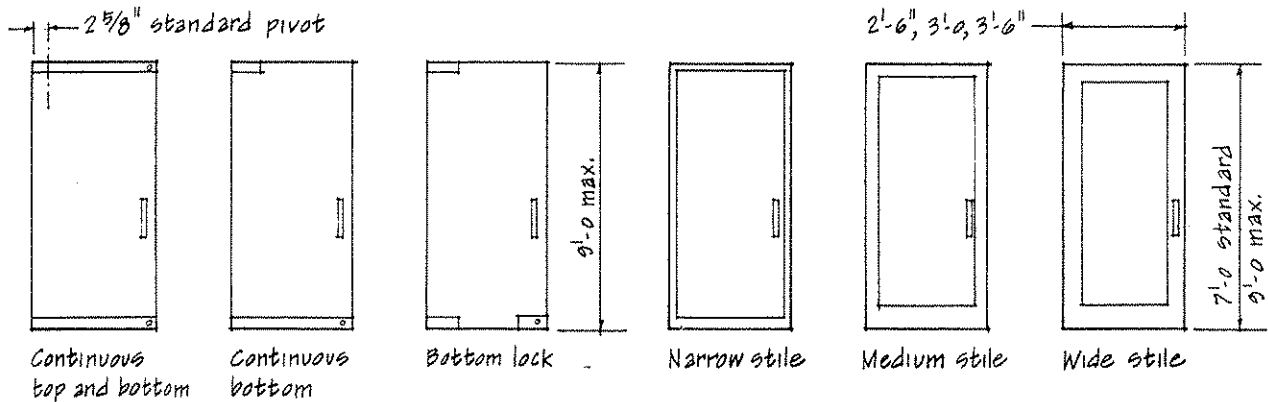


Alternate sill

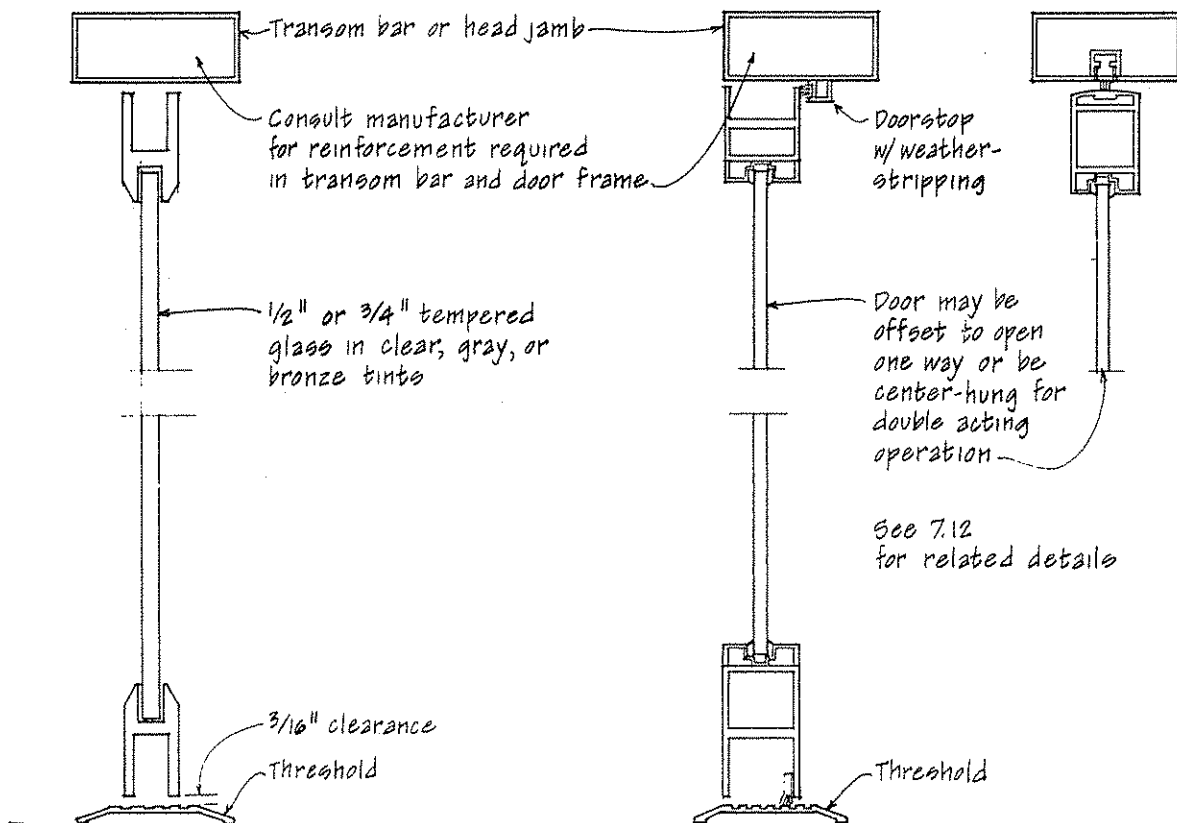


GLASS ENTRANCE DOORS

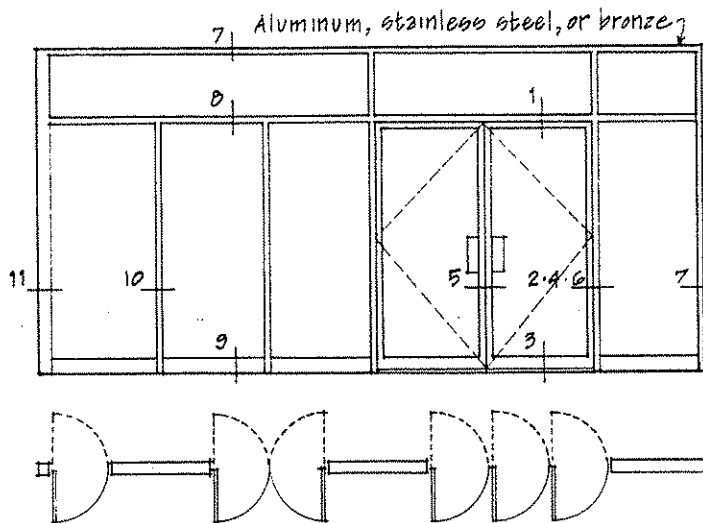
7.11

FRAMELESS DOORSFRAMED DOORS

- Consult local codes for safety requirements.
- Consult manufacturer for sizes, glazing options, and frame requirements.
- Frameless doors are difficult to weatherstrip effectively.



7.12 STOREFRONT ENTRANCES

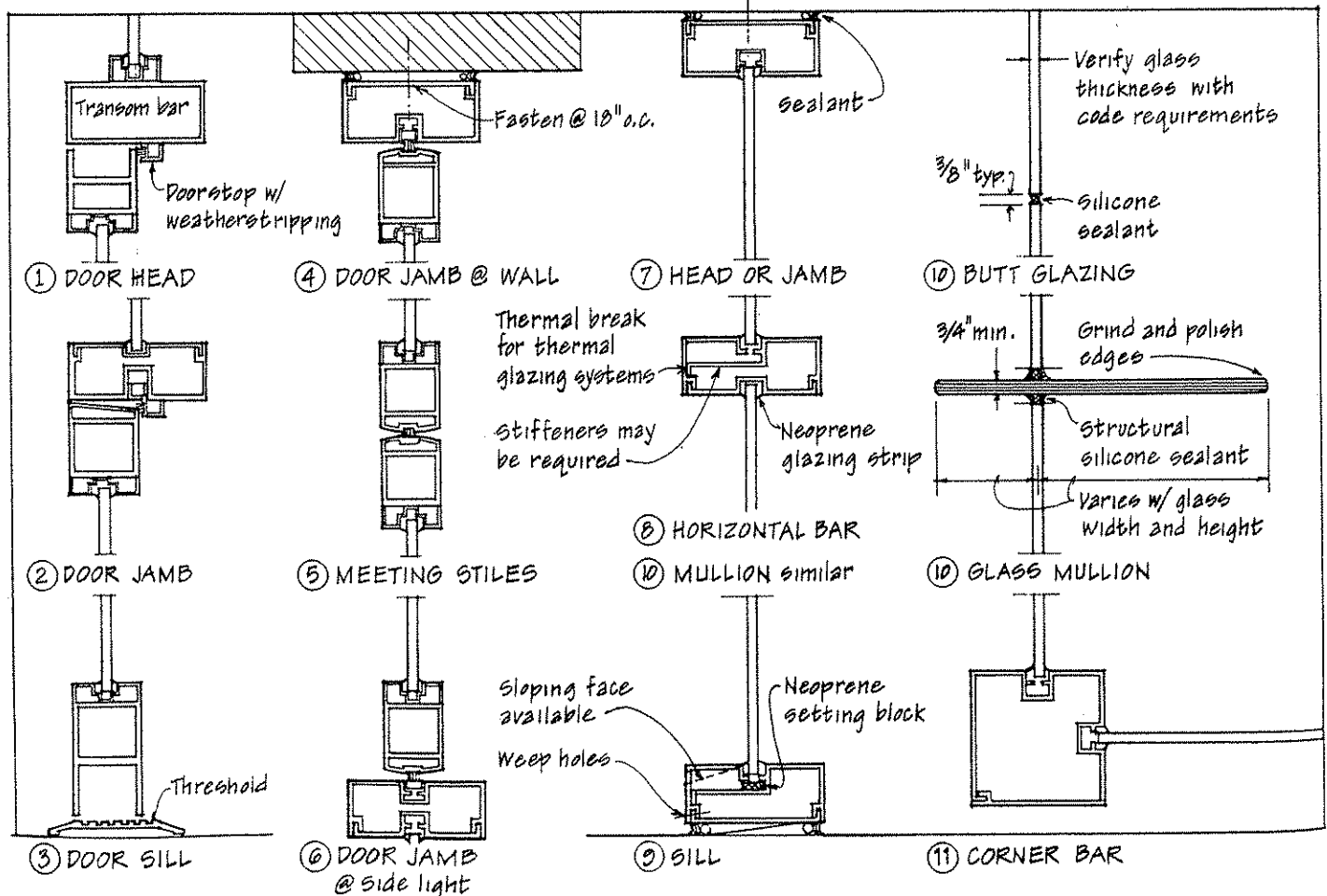


Door may be single or double acting, and be arranged in various ways.

Size and spacing of mullions are related to the glass thickness and the wind load on the wall plane. Limit the deflection normal to the wall plane to $1/200$ of each component's clear span; limit the deflection of glass supports to $1/300$ of the support distance.

Consult manufacturer for frame sizes, profiles, and installation details. Consult applicable code for safety glazing requirements.

All glass wall systems should be engineered. The thickness of the glass mullions is related to the width and height of the glass panels and the wind load on the wall plane. Consult glass manufacturer for sizing recommendations.



REVOLVING DOORS

7.13

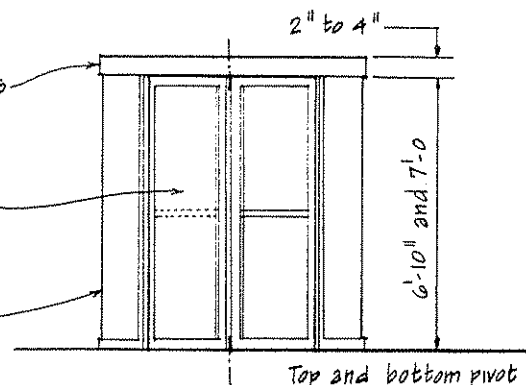
Revolving doors provide a continuous weatherseal, eliminate drafts, and hold heating and cooling losses to a minimum while accommodating a moderate flow of traffic.

- Can handle approximately 2000 persons per hour.
- Normally used in commercial and institutional buildings.
- 6'-6" diameter for general use; for large traffic areas, use 7'-0" diameter or greater.
- Heating and/or cooling source may be integral with or adjacent to enclosure.
- Optional speed control automatically aligns doors at quarter points when not in use and turns wings $3/4$ of a revolution at walking speed when activated by slight pressure.
- Door wings are collapsible in panic situations.
- Some codes may credit revolving doors with satisfying 50% of the legal exit requirements. Other codes do not credit revolving doors and require adjacent hinged doors for use as emergency exits.

Deck includes provision for ceiling lights; may be glazed with tempered glass

Doors of tempered glass with aluminum, stainless steel, or bronze frames

Enclosure may be metal or glass (tempered, wire, or laminated).

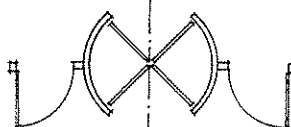
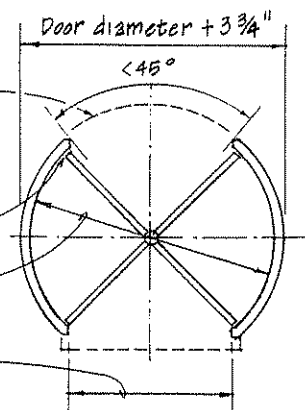


Line of soffit may be curved or straight.

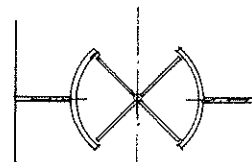
Weatherseal is provided by rubber and felt tip sweep at door stiles, and at top and bottom rails.

Door diameter

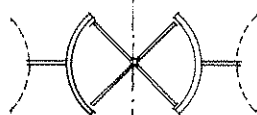
6'-6"	... 4'-5"	Opening
6'-8"	... 4'-6"	
6'-10"	... 4'-8"	
7'-0"	... 4'-9"	
7'-2"	... 4'-11"	
7'-4"	... 5'-0"	



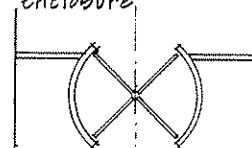
Enclosure flanked by hinged doors



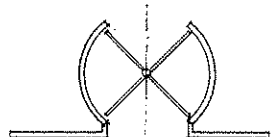
Side lights centered on enclosure



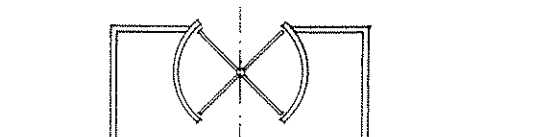
Bank of enclosures with side lights between



Enclosure projecting from side lights



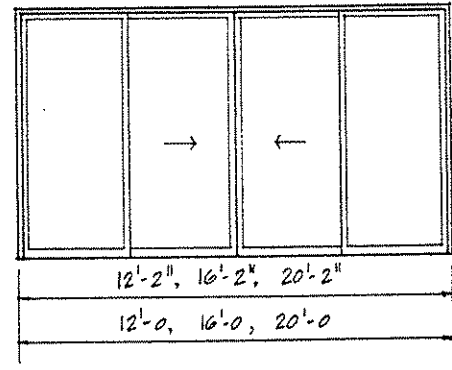
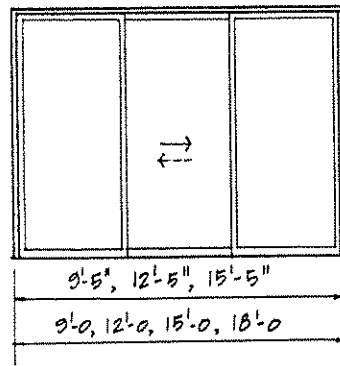
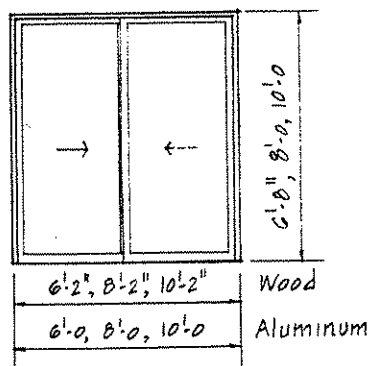
Enclosure set within a wall plane



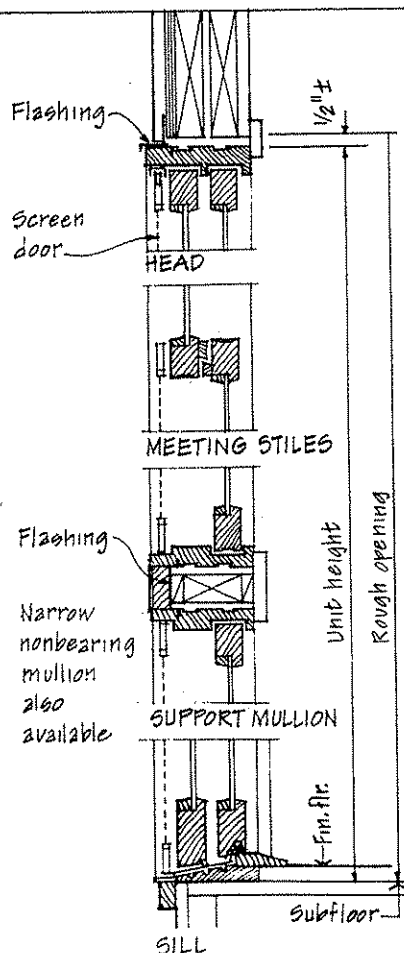
Enclosure set back within a wall recess

REVOLVING DOOR LAYOUTS

7.14 SLIDING GLASS DOORS

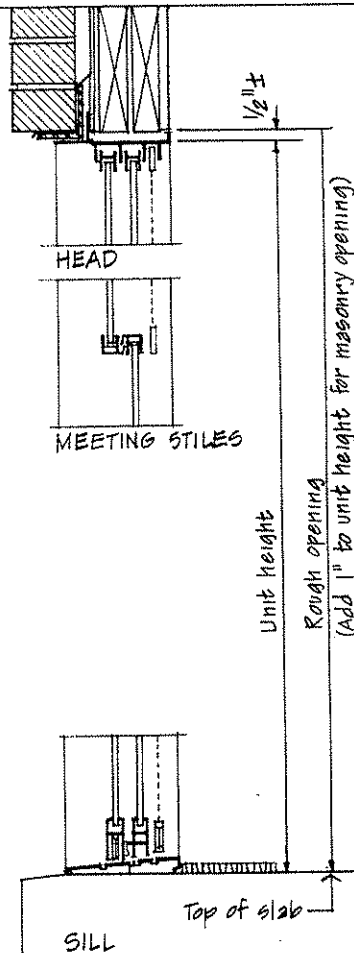


Above dimensions are nominal stock sizes; consult manufacturer for rough or masonry openings required. As a guide, add 1" to nominal width for rough openings, and 3" for masonry openings.



WOOD SLIDING DOOR
in wood frame

(Hatched sections are normally supplied by manufacturer.)



METAL SLIDING DOOR
in brick veneer wall

Residential sliding glass doors are available with wood, aluminum, or steel frames. Wood frames may be treated with preservative, primed for painting, or clad in aluminum or vinyl. Metal frames are available in a variety of finishes, with thermal breaks and integral windproof mounting fins.

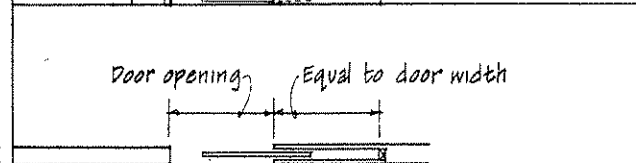
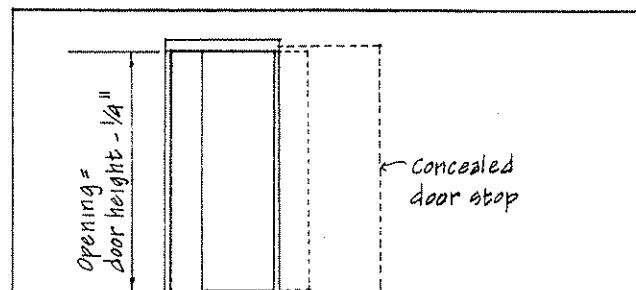
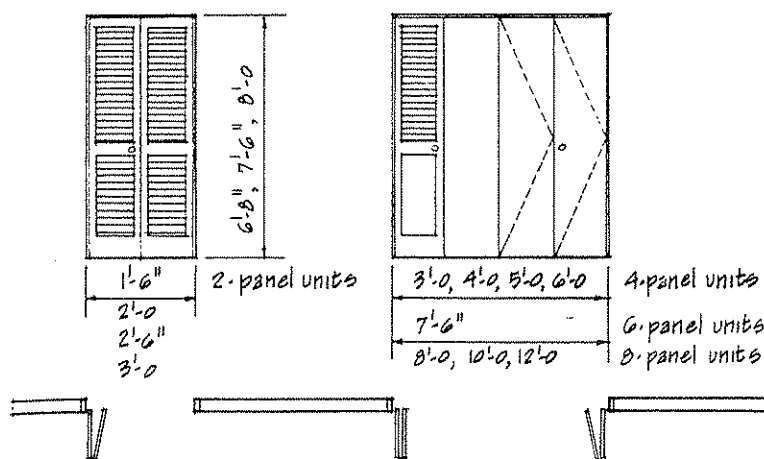
For safety, all glazing should be of tempered glass. For energy conservation, units are available with insulating glass.

Sliding glass doors are manufactured as standard units complete with operating hardware and weatherstripping. Screen and operating door panels may be on the interior or exterior.

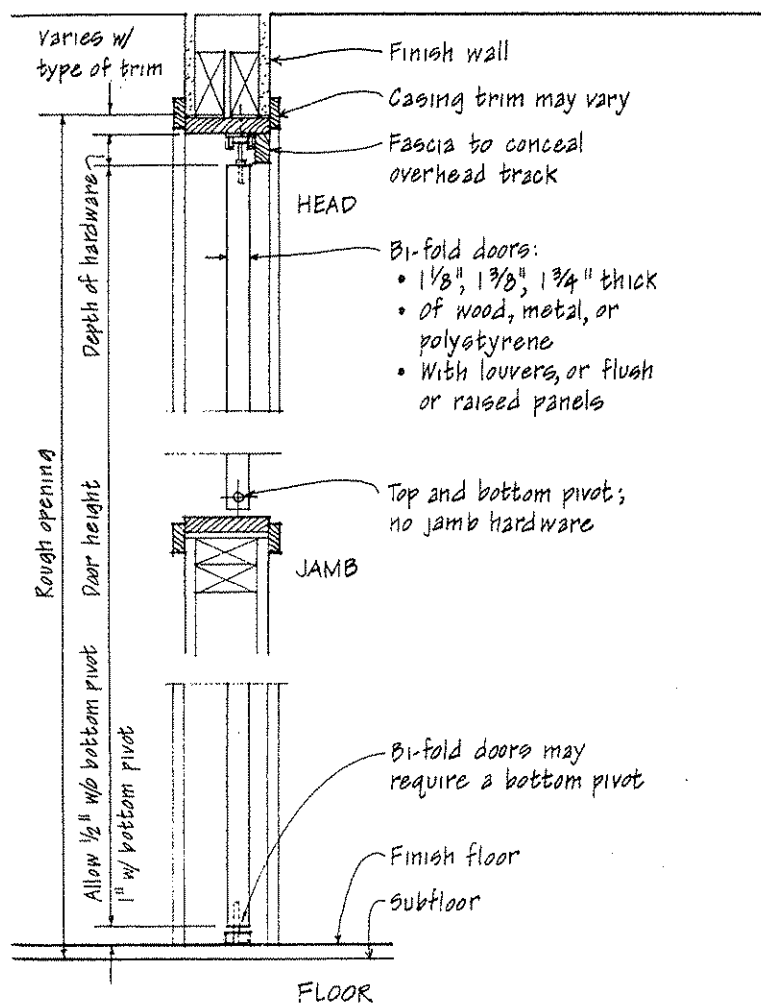
Consult manufacturer for stock sizes, required rough or masonry openings, glazing options, and installation details.

FOLDING AND POCKET SLIDING DOORS

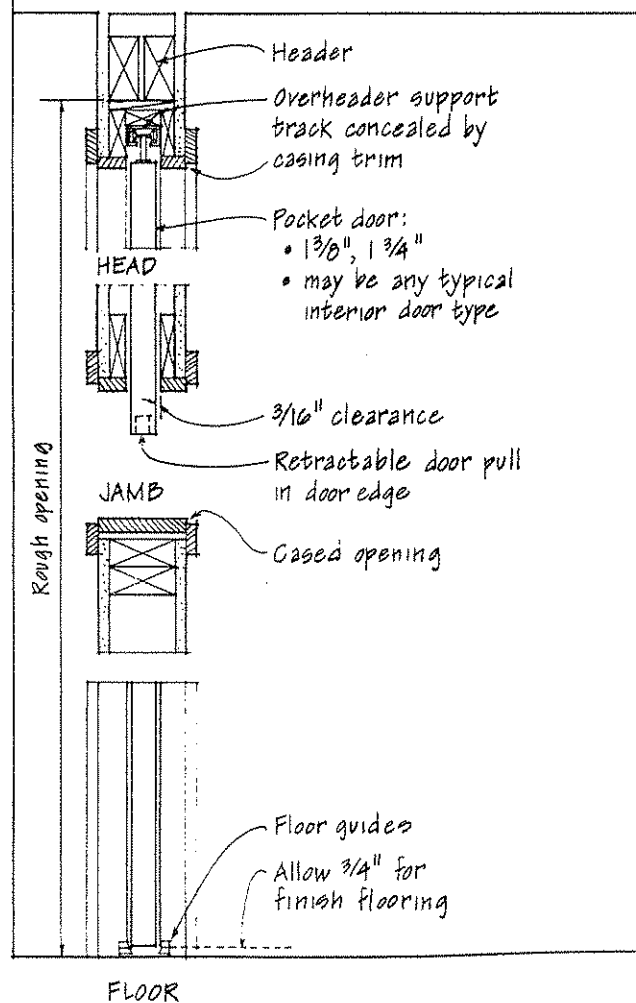
7.15



FOLDING DOORS

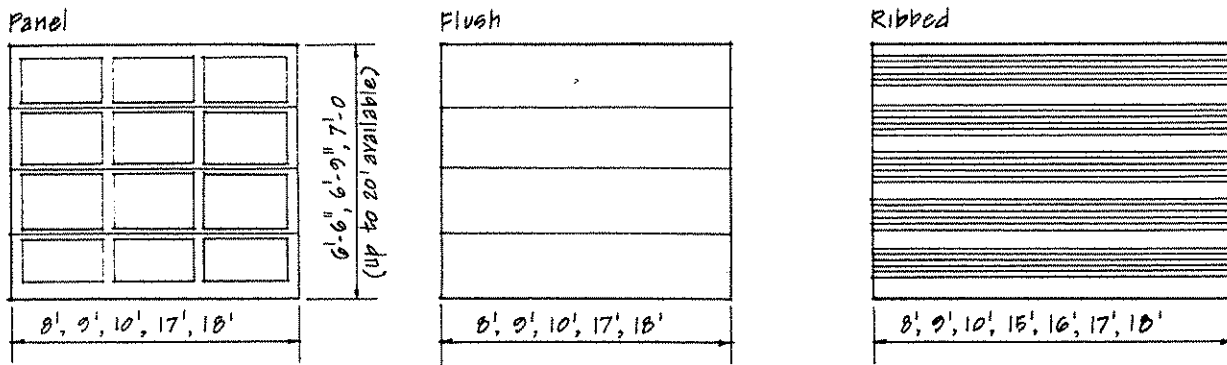


POCKET SLIDING DOOR

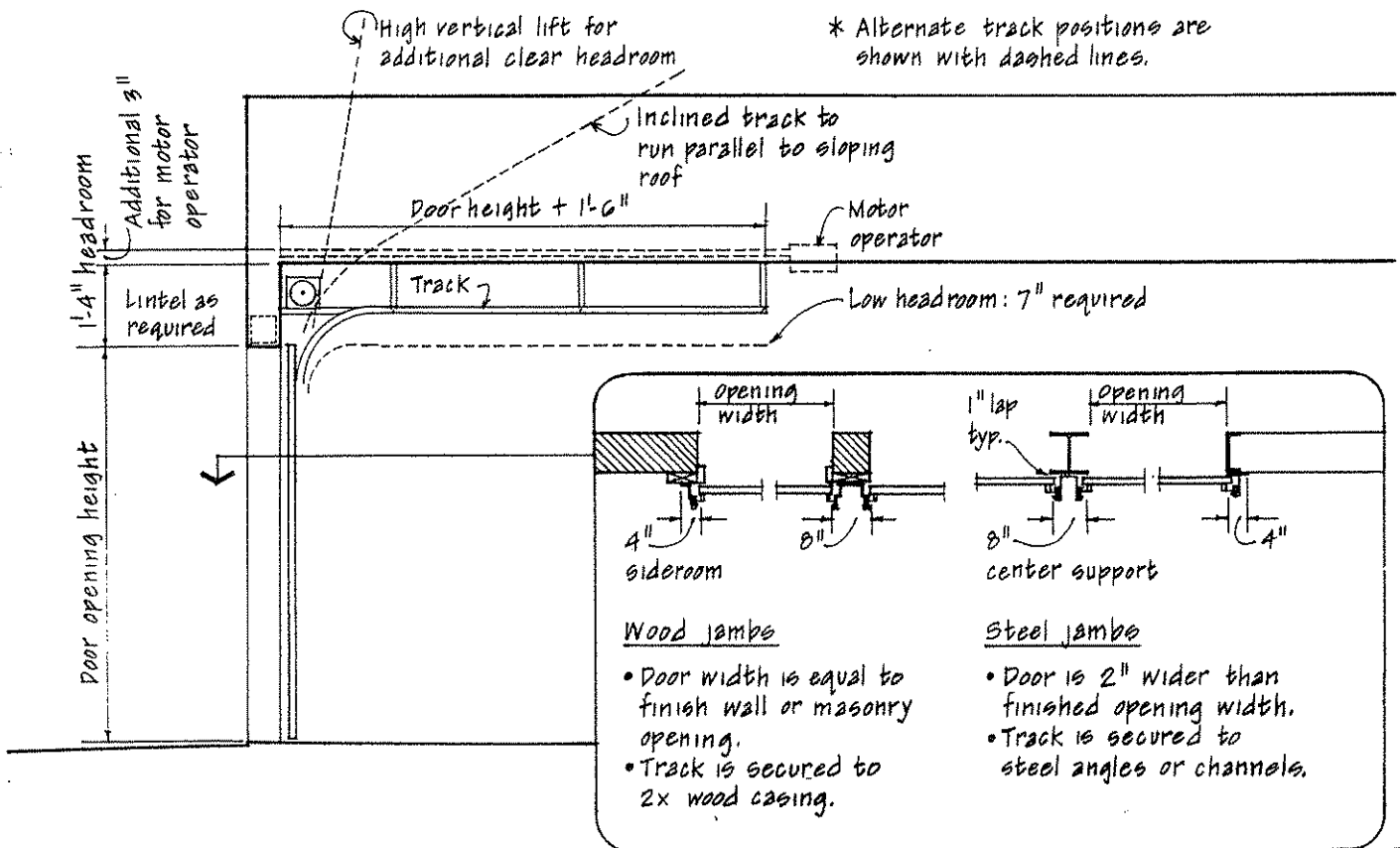


Generalized conditions for wood frame construction are illustrated. Details for hollow metal doors and frames are similar. Consult hardware manufacturer for installation details.

7.16 GARAGE AND OVERHEAD DOORS



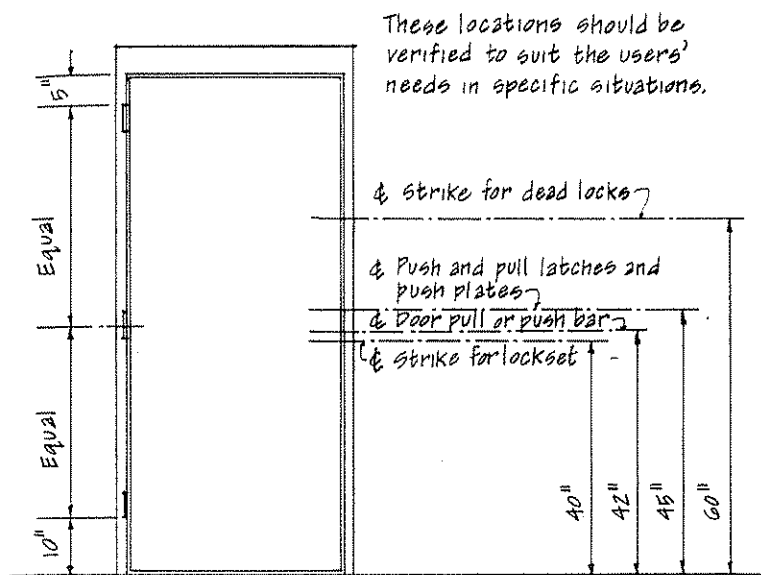
Doors may be of wood, steel, aluminum, or fiberglass. Glazing in panel design may be located as desired. In addition to the sizes indicated above, commercial overhead doors can be up to 20' high and 30' wide. Consult manufacturer for details.



Overhead doors may be operated manually, or by a chain hoist or electric motor. Chain hoist and motor operations may require additional head, side, and back room.

DOOR HARDWARE

7.17



RECOMMENDED DOOR HARDWARE LOCATIONS

HARDWARE FINISHES

BHMA Code	U.S. No.	Finish
G00	U9P	Primed for painting (steel)
G03	U92G	Zinc plated (steel)
G05	U93	Bright brass, clear coated
G06	U94	Satin brass, clear coated
G11	U99	Bright bronze, clear coated
G12	U910	Satin bronze, clear coated
G13	U910B	Oxidized satin bronze, oil rubbed
G18	U914	Bright nickel plated, clear coated (brass)
G19	U915	Satin nickel plated, clear coated (brass)
G22	U919	Flat black coated (brass, bronze)
G23	U920	Light oxidized bright bronze
G24	U920A	Dark oxidized statuary bronze
G25	U926	Bright chromium plated (brass, bronze)
G26	U926D	Satin chromium plated (brass, bronze)
G28	U928	Satin aluminum, clear anodized
G29	U932	Bright stainless steel
G30	U932D	Satin stainless steel
G84	-	Black chrome, bright (brass, bronze)
G85	-	Black chrome, satin (brass, bronze)

Builders' Hardware Manufacturers Association (BHMA) codes are given with the nearest U.S. equivalent.

Door opens inward; hinges on left



Left hand (LH)

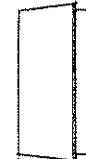
Door opens inward; hinges on right



Right hand (RH)

Direction of travel is assumed to be from the outside in.

Door opens outward; hinges on left



Left hand reverse (LHR)

Door opens outward; hinges on right



Right hand reverse (RHR)

The above door hand conventions are used in specifying door hardware such as locksets and closers.

DOOR HAND CONVENTIONS

FINISH DOOR HARDWARE includes:

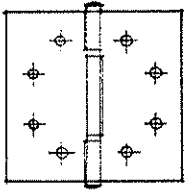
- Locksets
- Locks, latches, bolts,
- Cylinder and stop works
- Operating trim
- Hinges
- Closers
- Panic hardware
- Push and pull bars and plates
- Kick plates
- Stops and holders
- Thresholds
- Weatherstripping
- Door tracks and guides

SELECTION FACTORS:

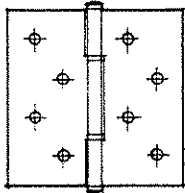
- Function and ease of operation
- Recessed or surface-mounted installation
- Material, finish, texture, and color
- Durability in terms of:
 - Anticipated frequency of use
 - Possible exposure to weather or corrosive conditions.

BASE MATERIALS include brass, bronze, steel, stainless steel, and aluminum.

7.18 DOOR HINGES



Template



Non-template (for wood doors)

Butt hinges are normally used with wood and hollow metal doors and frames. They are mortised into the door edge and jamb so that only the knuckle is visible when the door is closed.

The pin in the knuckle may be removable (loose) or fixed (non-rising). Self-locking pins which cannot be removed when the door is closed are also available for security.

For doors up to $2\frac{1}{4}$ " thick: $\frac{5}{16}$ "
(over $2\frac{1}{4}$ " thick: $\frac{7}{16}$ ")

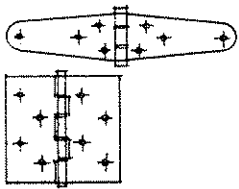
For doors up to $2\frac{1}{4}$ " : $\frac{1}{4}$ "
(over $2\frac{1}{4}$ " : $\frac{3}{8}$ ")

Check clearance required for surrounding trim.

HINGE SIZES

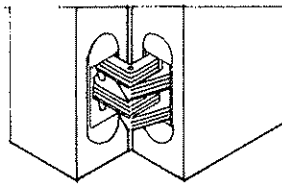
Width is determined by door thickness and clearance required.
Height is determined by door width and thickness.

Door thickness	Door width	Clearance required	Hinge height	Hinge width
$\frac{3}{4}$ " to $\frac{7}{8}$ " (cabinet)	to 24"		$2\frac{1}{2}$ "	
$\frac{7}{8}$ " to $1\frac{1}{8}$ " (screen)	to 36"		3"	
$1\frac{3}{8}$ "	to 36"	$\frac{1}{4}$ "	$3\frac{1}{2}$ " - 4"	$3\frac{1}{2}$ "
$1\frac{3}{4}$ "	to 36"	1"	4"	4"
	36" to 48"	$\frac{1}{2}$ "	$4\frac{1}{2}$ "	$4\frac{1}{2}$ "
$2\frac{1}{4}$ "	to 42"	1"	5"	5"
	over 42"	2"	6"	6"



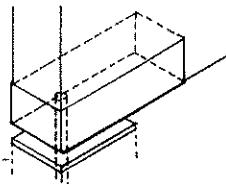
Surface hinges

- Used where mortising of door or jamb is not possible



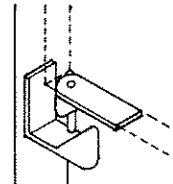
Invisible hinge

- Hinge is completely concealed when door is closed



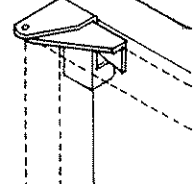
Floor hinge

- Used with mortise pivot at door head for double-acting door; may be provided with a closer mechanism



Gravity type pivot

- Used with double-acting swing doors (eg. cafe door)



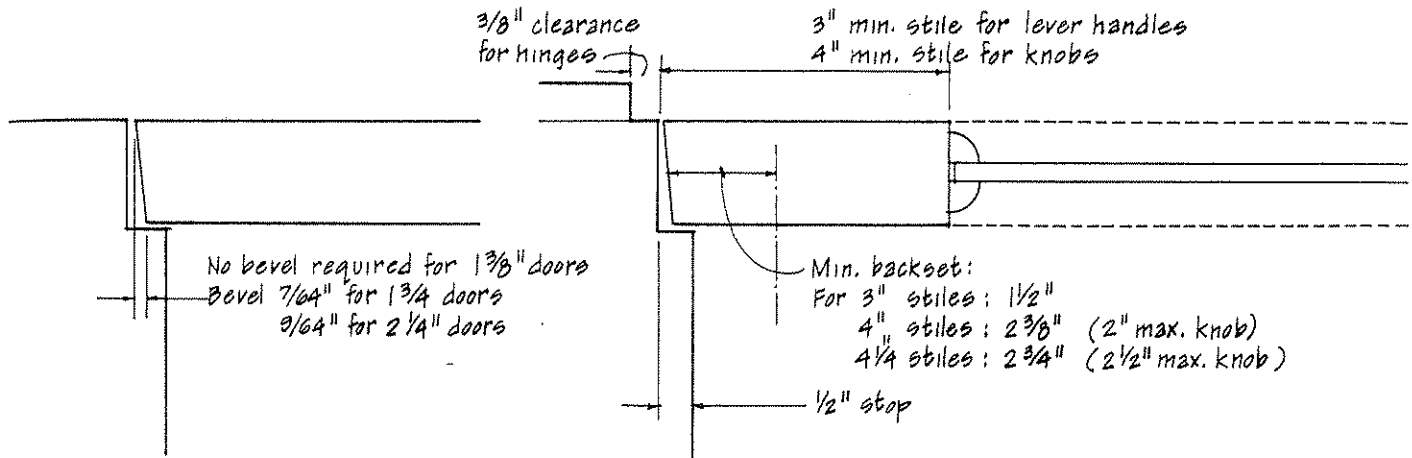
Pivot hinge

- used primarily with cabinet doors

SPECIAL-PURPOSE HINGES

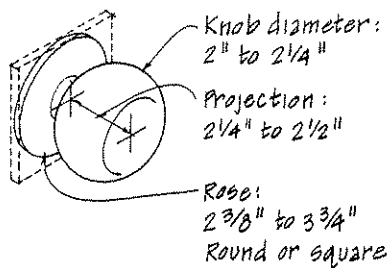
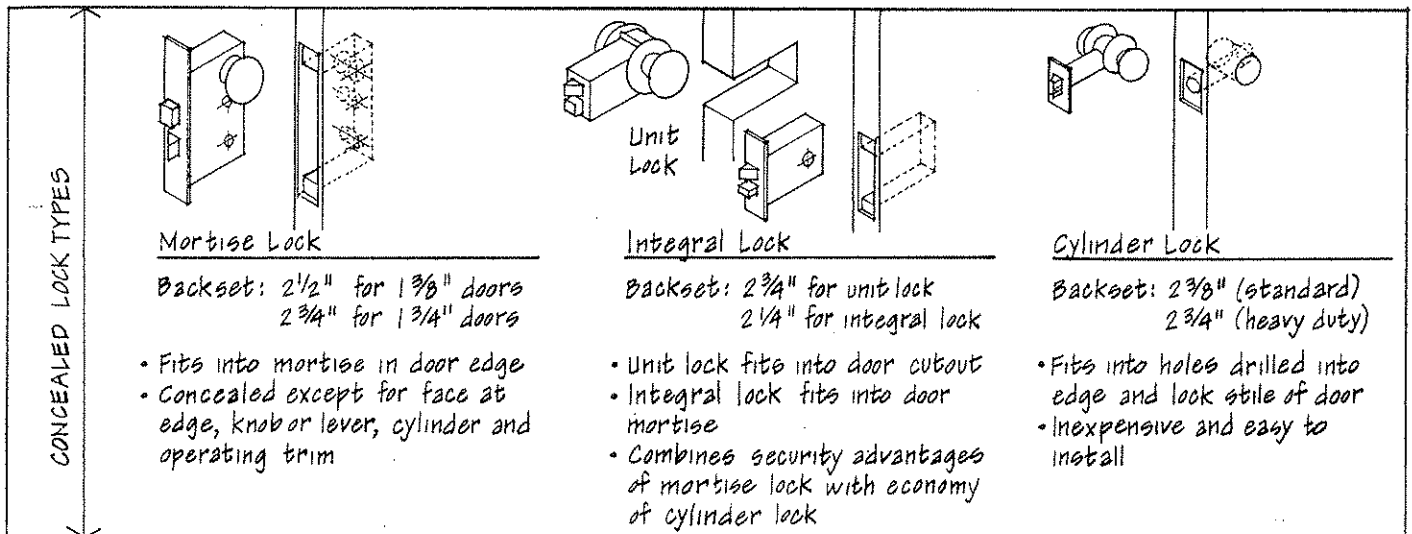
DOOR LOCKSETS

7.19

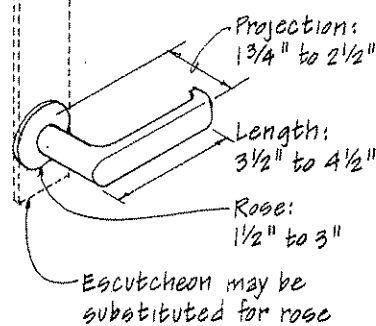


DOOR BEVEL REQUIREMENTS

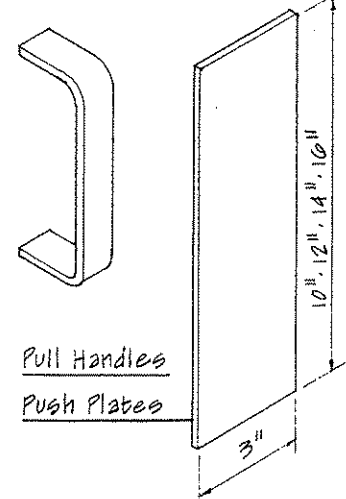
DOOR STILE REQUIREMENTS FOR HARDWARE



Door Knobs

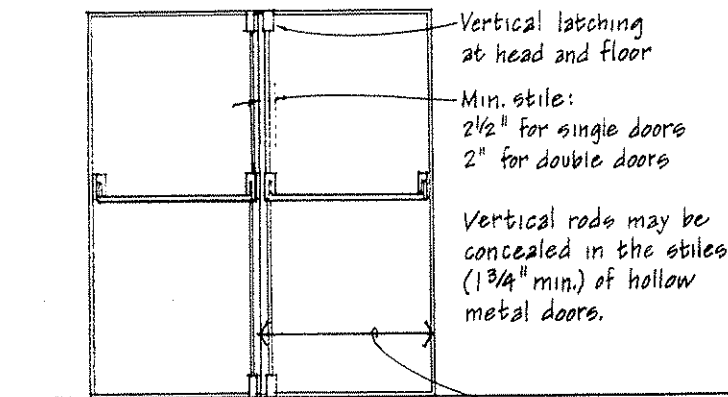


Lever Handles



* Refer to manufacturers' catalogs for lockset functions, installation requirements, trim designs, dimensions, and finishes.

7.20 DOOR PANIC HARDWARE AND CLOSERS



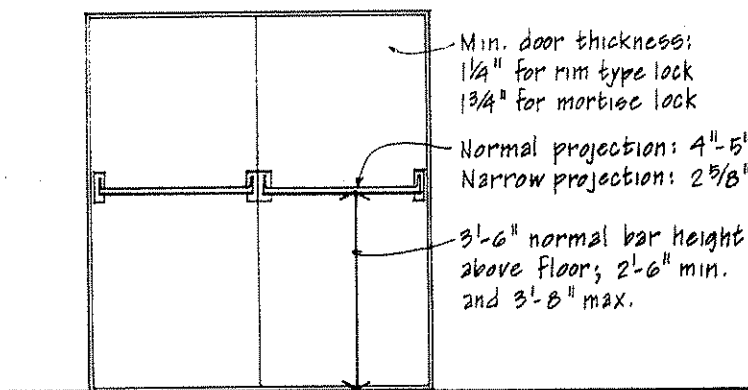
Exposed vertical rod type

DOOR PANIC HARDWARE

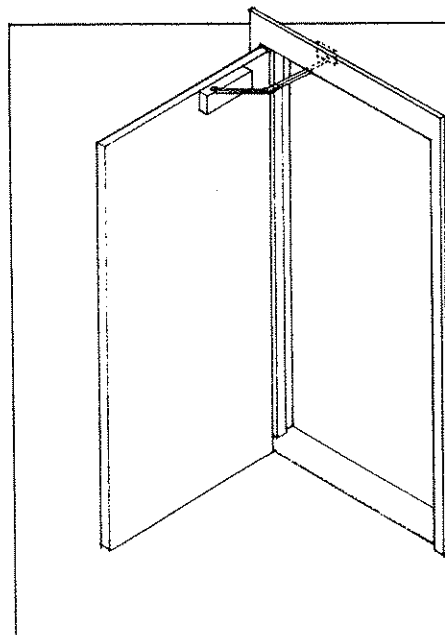
Panic hardware is a door-latching assembly that disengages when pressure is applied on the push bar. The push bar should extend across at least one-half the width of the door leaf on which it is installed.

Building codes require the use of panic hardware on fire exit doors in certain building occupancies. Consult the applicable code for details.

The width, swing, and location of required fire exits are also regulated by building codes according to use and occupancy load. See A.10



Concealed type with lateral latching



Closer may be exposed or concealed with the arms mounted in the door, overhead, or in the floor construction.

DOOR CLOSERS

Door closers automatically close doors quickly but quietly through various types of hydraulic mechanisms. They help reduce the shock a large, heavy, or heavily used door transmits upon closing to its frame, hardware, and surrounding wall.

Door closers are also required on fire-rated doors that protect openings in fire-resistant walls. Refer to the applicable code for details.

Types of installation:

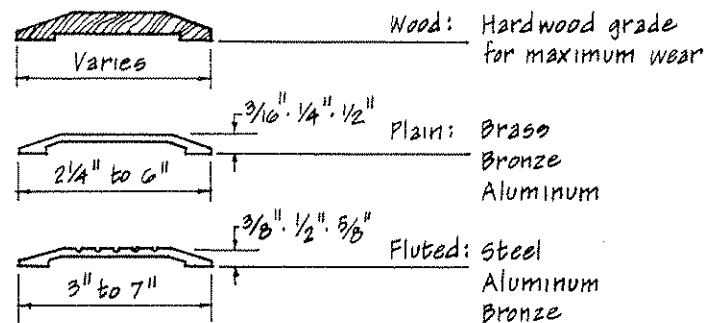
- Parallel arm (for minimum projection)
- Soffit bracket
- Flush bracket
- Corner bracket (for 180° swing)
- Top jamb (for maximum headroom)

DOOR THRESHOLDS AND WEATHERSTRIPPING

7.21

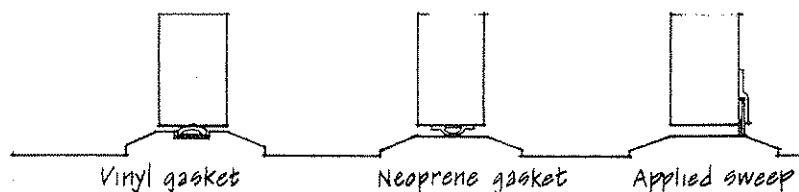
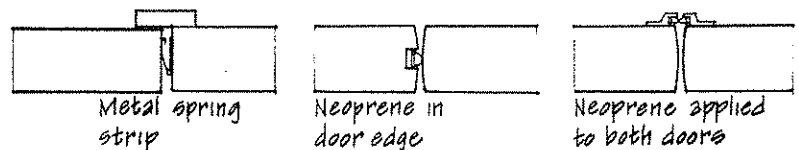
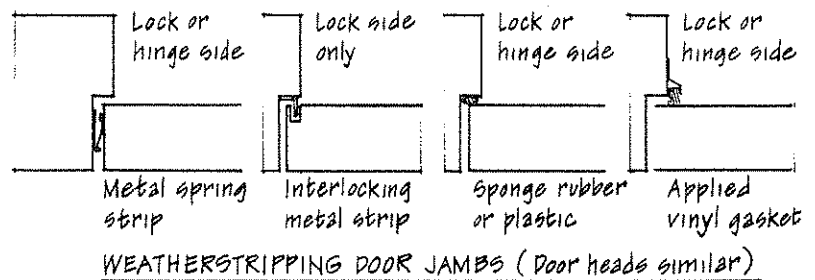
Thresholds conceal the joints between flooring materials at doorways and serve as a weather barrier at exterior sills.

- Thresholds have recessed undersides to fit snugly against the flooring or sill.
- When installed at exterior sills, joint sealant is used for a tight seal.
- Metal thresholds may be cast or covered with abrasive material to provide a non-slip surface.

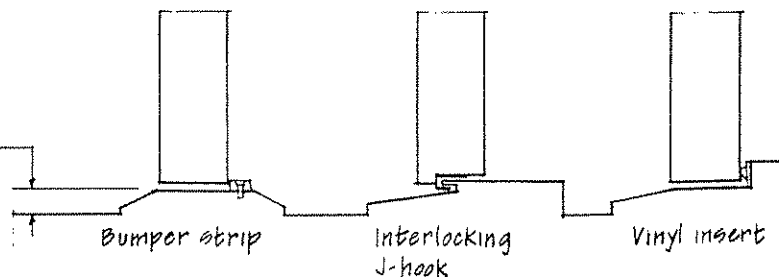


Weatherstripping of exterior doors reduces air infiltration and the resulting heating and cooling loss. It can also prevent dust and wind-blown rain from penetrating a building's interior.

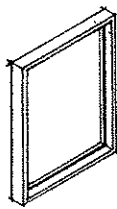
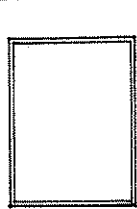
- Weatherstripping may be fastened to the door edge or face, or to the door frame and threshold.
- The weatherstripping material should be durable under extended use, non-corrosive, and replaceable.
- Basic types of weatherstripping include:
 - Metal spring-tensioned strip of aluminum, bronze, or stainless or galvanized steel
 - Vinyl or neoprene gaskets
 - Sponge plastic or rubber strips
 - Woven pile strips
- Weatherstripping is often supplied by the manufacturer of:
 - Sliding glass doors
 - Glass entrance doors
 - Revolving doors
 - Garage and overhead doors



$\frac{1}{2}$ " max. for handicapped access



7.22 WINDOW TYPES BY OPERATION

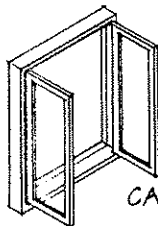
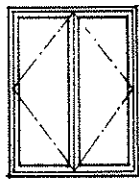


FIXED

Ventilation

0 %

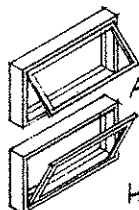
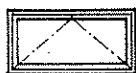
- Consists of a frame and stationary sash.
- When used in conjunction with operable window units, thickness of sash should approximate cross-sectional dimension of operating sash.



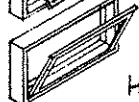
CASEMENT

100 %

- Operating sash is side-hinged, usually swinging outward.
- Pair of sash may close on each other or on a vertical mullion.
- Able to direct ventilation.



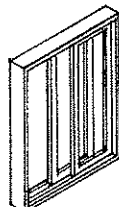
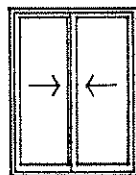
AWNING



HOPPER

100 %

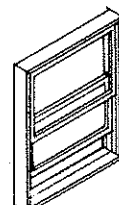
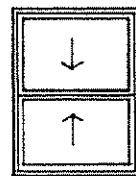
- Similar to casement windows but hinged at top (awning) or bottom (hopper).
- May be stacked vertically with sash closing on each other or on meeting stiles.
- Able to direct ventilation.
- Awning windows offer a degree of rain protection.



SLIDING

50-66 %

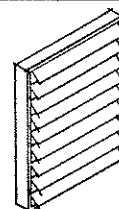
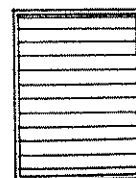
- May consist of 2 sash of which one slides horizontally (50% ventilation), or of 3 sash of which the middle is fixed while the other two slide (66% ventilation).



DOUBLE-HUNG

50 %

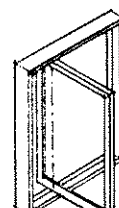
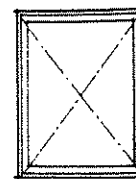
- Sash move vertically and are held in the desired position by friction fit against the window frame or by various balancing devices.
- Single-hung windows are similar but one sash is fixed.



JALOUSIE

100 %

- Similar in principle to awning windows. Blade material may be transparent, translucent, or opaque.
- Difficult to weatherstrip effectively; used primarily in warm climates for ventilation.



PIVOTING

(100 %)

- Pivoting sashes usually remain closed in air-conditioned buildings, and are opened only when needed for cleaning, maintenance, and emergency ventilation.

WINDOW ELEMENTS

7.25

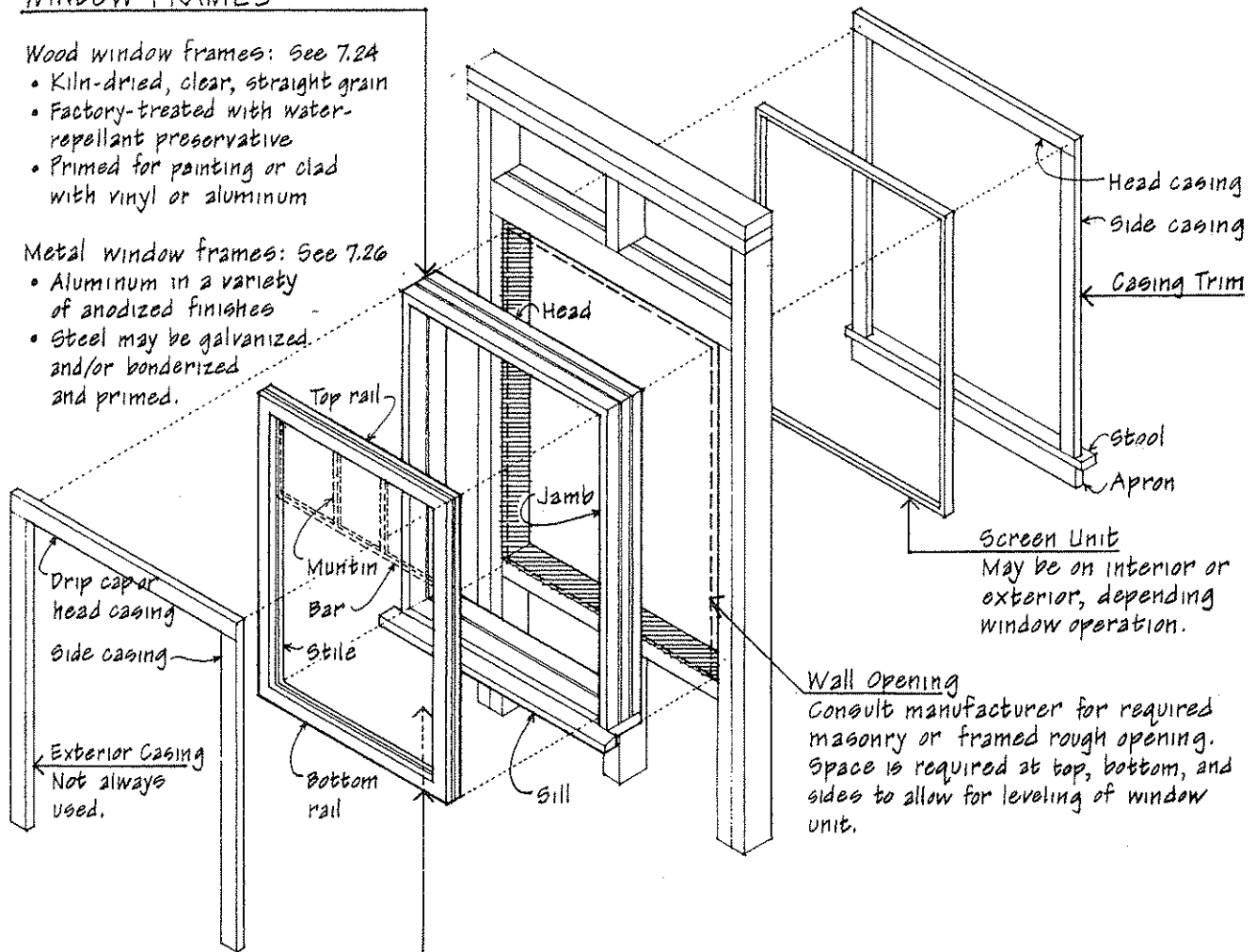
WINDOW FRAMES

Wood window frames: See 7.24

- Kiln-dried, clear, straight grain
- Factory-treated with water-repellant preservative
- Primed for painting or clad with vinyl or aluminum

Metal window frames: See 7.26

- Aluminum in a variety of anodized finishes
- Steel may be galvanized and/or bonderized and primed.



SASH AND GLAZING

The sash frames the glass and forms the operating part of a window unit. Its section profile varies with material, manufacturer, and type of operation.

Single glazing offers little resistance to heat flow. For a reasonable thermal resistance value (R), double glazing or a separate storm is required. Using glass with a reflective coating or triple glazing is an option if a higher R -value is required.

Just as important as a window's insulating value is its weathertightness. Operating sash should have continuous weatherstripping. The joint between the window frame and the surrounding wall should be sealed, and have a windbreak built into the detail.

CODE REQUIREMENTS

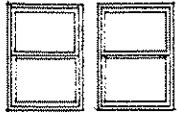
In selecting a window unit, review the building code requirements for:

- Natural light and ventilation of habitable spaces.
- Resistance to wind loads
- Thermal insulation value of the window assembly
- Clear opening of any window that serves as an emergency exit for a residential sleeping space.

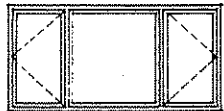
7.24 WOOD WINDOWS



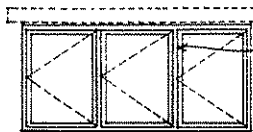
Single unit



Side by side



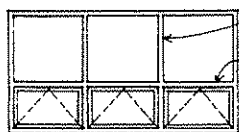
Flanking a fixed unit



Banked

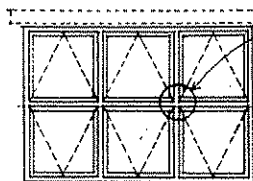
Window manufacturers offer various combinations of both fixed and venting units.

Structural mullions would reduce span of header.



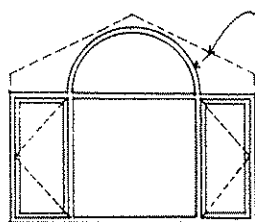
Fixed over vent units

Mullion
Transom



Grouped

Reinforcement required when 4 windows meet @ a common corner



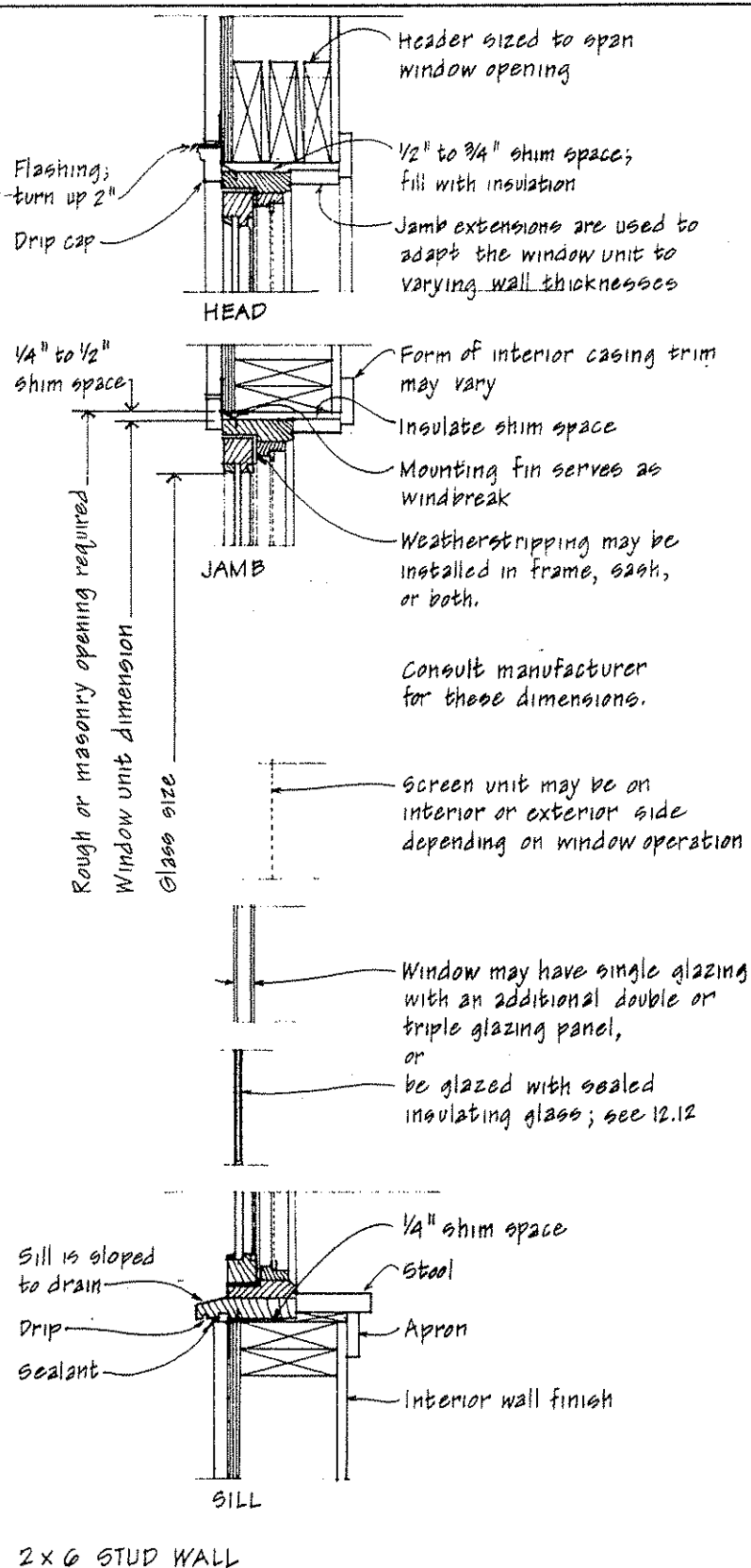
Special shapes

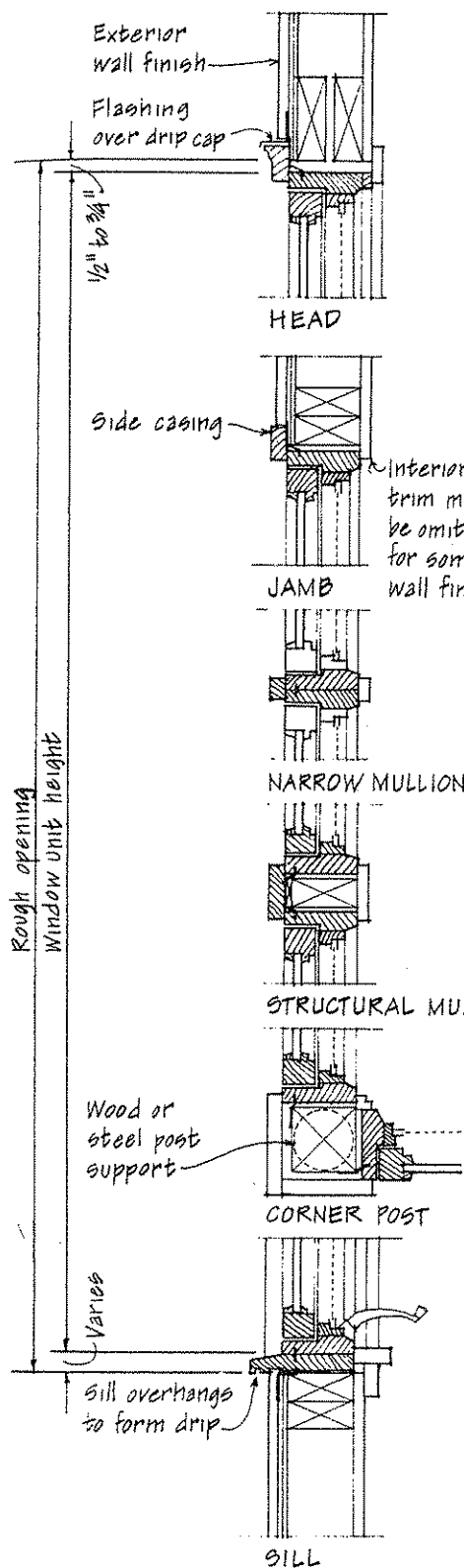
Circular or trapezoidal



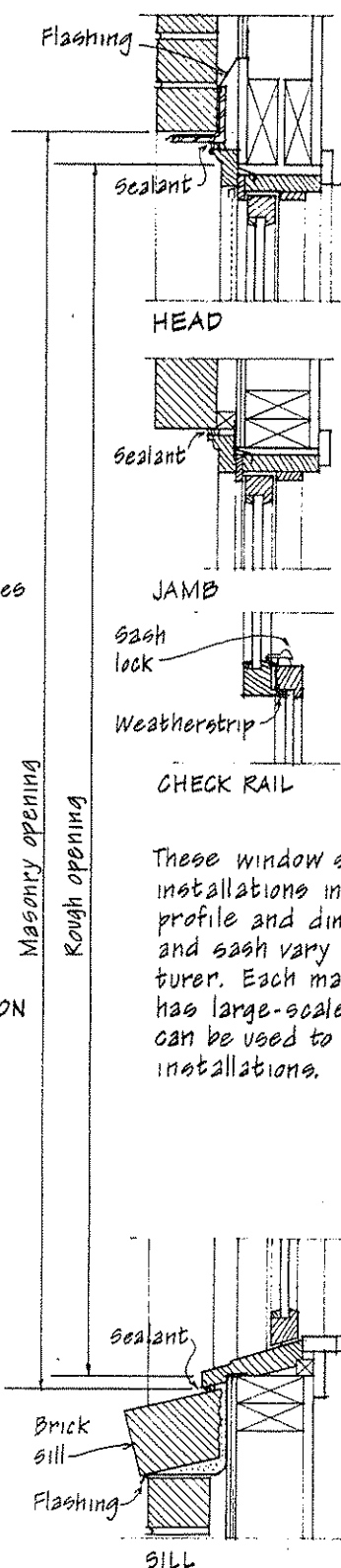
Bay windows

30°, 45°, or 60°

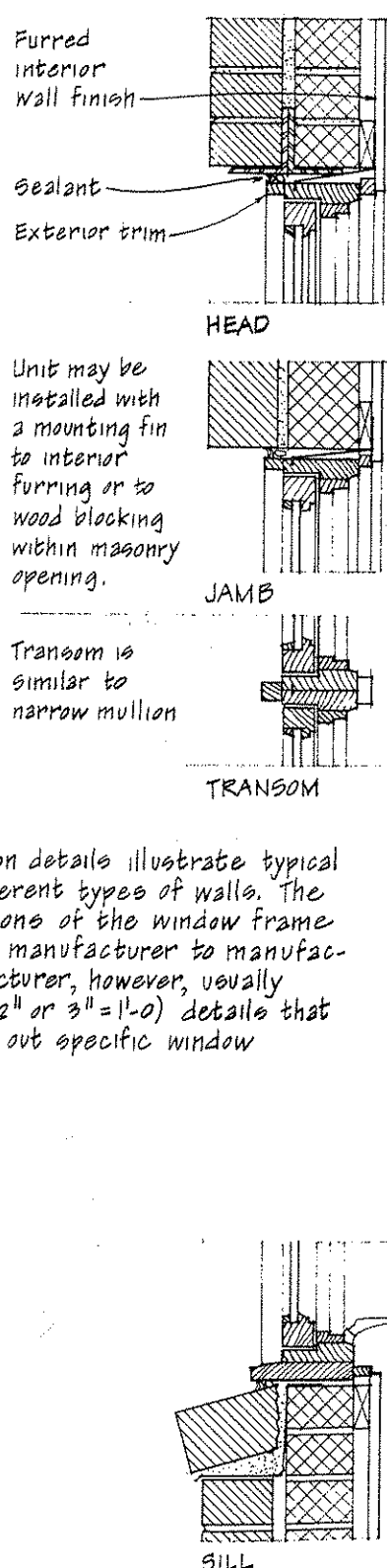




2x4 STUD WALL



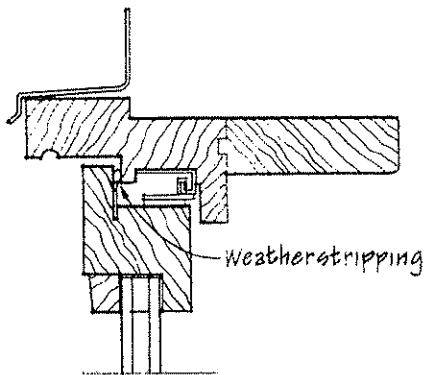
BRICK VENEER WALL



8" MASONRY WALL

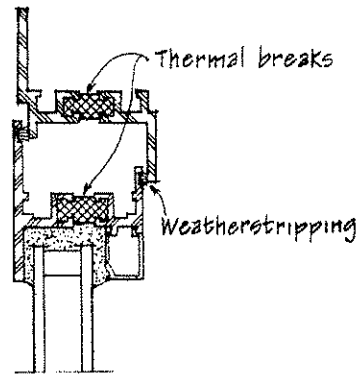
These window section details illustrate typical installations in different types of walls. The profile and dimensions of the window frame and sash vary from manufacturer to manufacturer. Each manufacturer, however, usually has large-scale (1 1/2" or 3" = 1'-0") details that can be used to work out specific window installations.

7.26 METAL WINDOWS



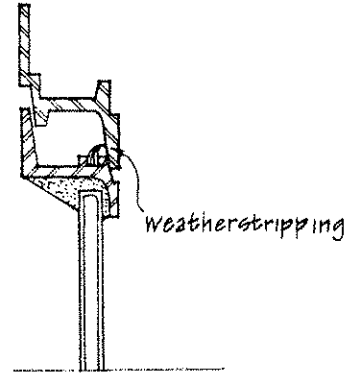
WOOD FRAMES

Wood is a fairly good thermal insulator. The size of the sash section depends on the type and thickness used.



ALUMINUM FRAMES

Aluminum frames should have a plastic or synthetic rubber thermal break to interrupt the flow of heat from the warm to the cool side.



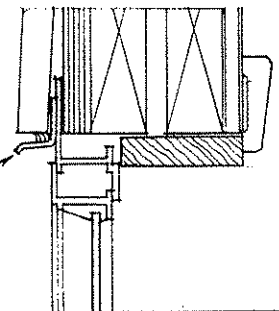
STEEL FRAMES

Steel frame and sash sections are more rigid than aluminum sections and are usually thinner in profile.

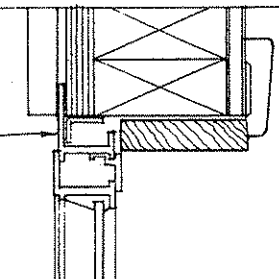
Rain drips are required for windows that are flush with the exterior wall and for transom bars or horizontal mullions.

Metal window frames usually have fins that serve as a windbreak for the joint between the window unit and the wall. The fins may also be used for attaching the frame to the supporting structure.

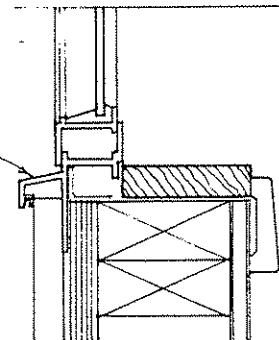
The head, jamb, and sill sections are usually similar in profile. Head and sill sections, however, may have integral rain drips.



HEAD

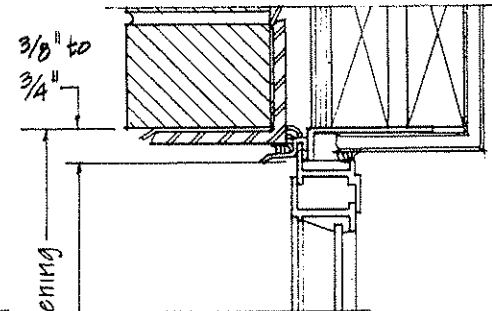


JAMB

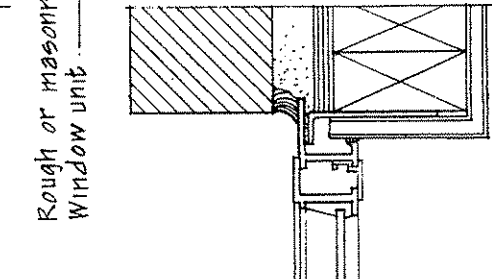


SILL

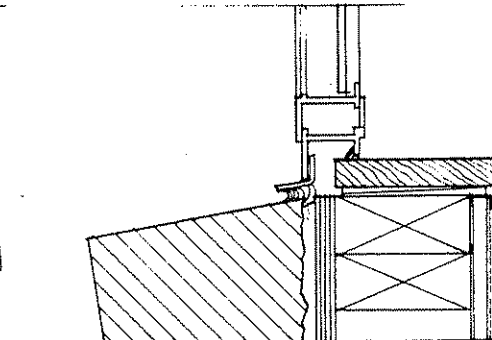
WOOD STUD WALL



HEAD



JAMB



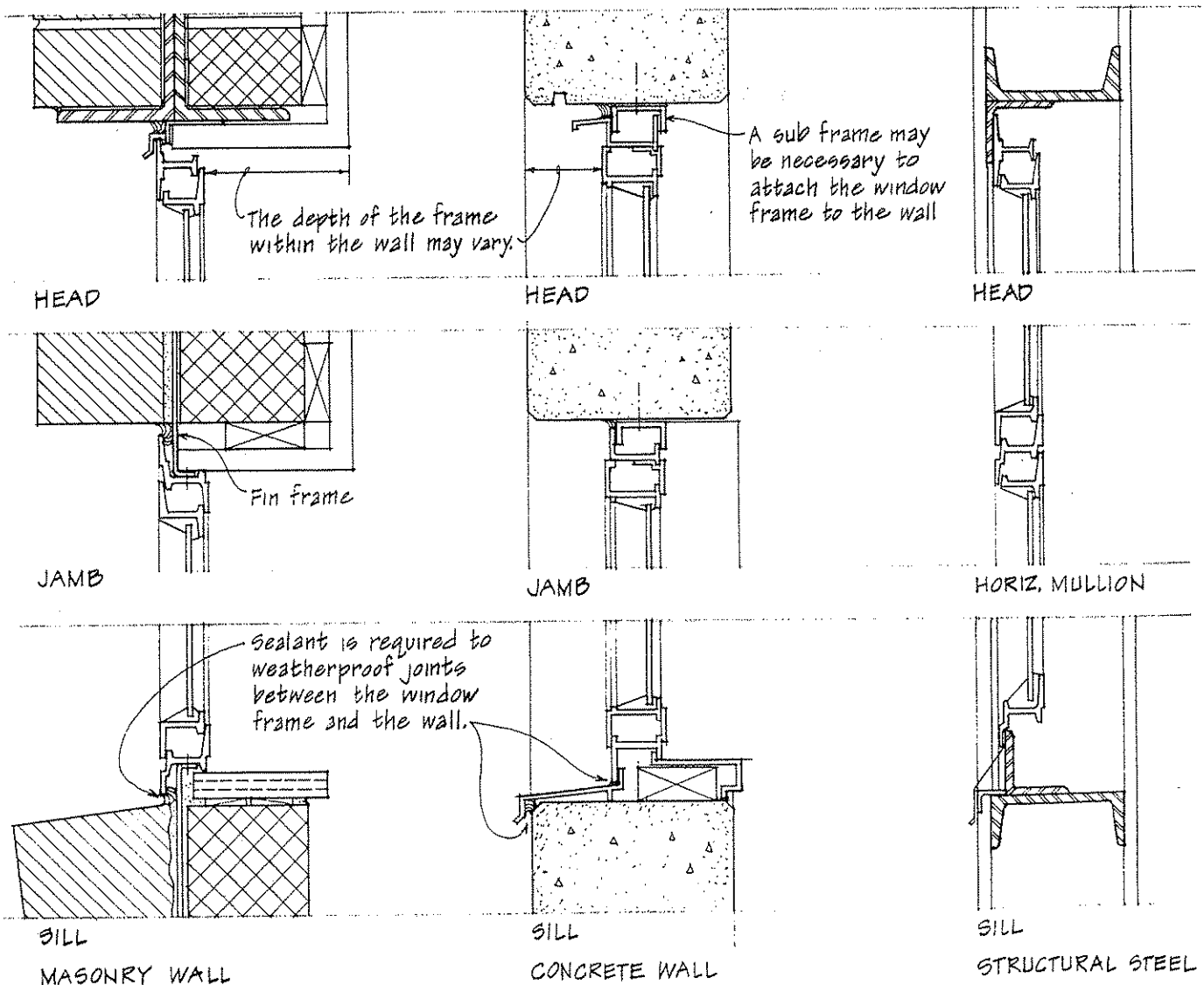
SILL

BRICK VENEER WALL

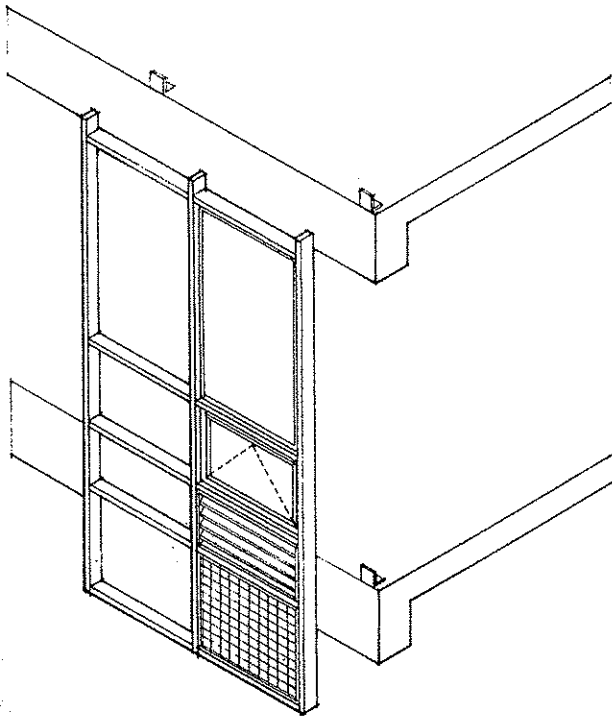
Shown on this and the preceding page are generalized conditions for the installation of metal windows in different types of walls. Since the frame and sash sections vary greatly from one manufacturer to the next, refer to the manufacturer's literature for:

- Large-scale details of frame and sash
- Methods of attachment
- Rough or masonry openings required
- Alloy, weight, and thickness of sections
- Finishes available
- Glazing method and options
- Thermal performance of window assembly

Some manufacturers offer stock sizes while others only do custom work.



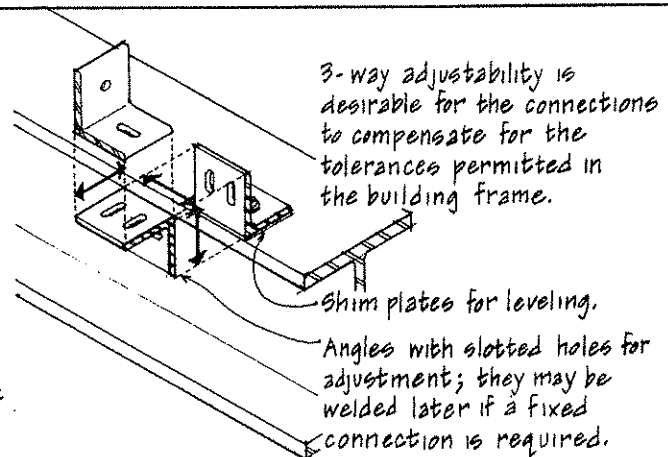
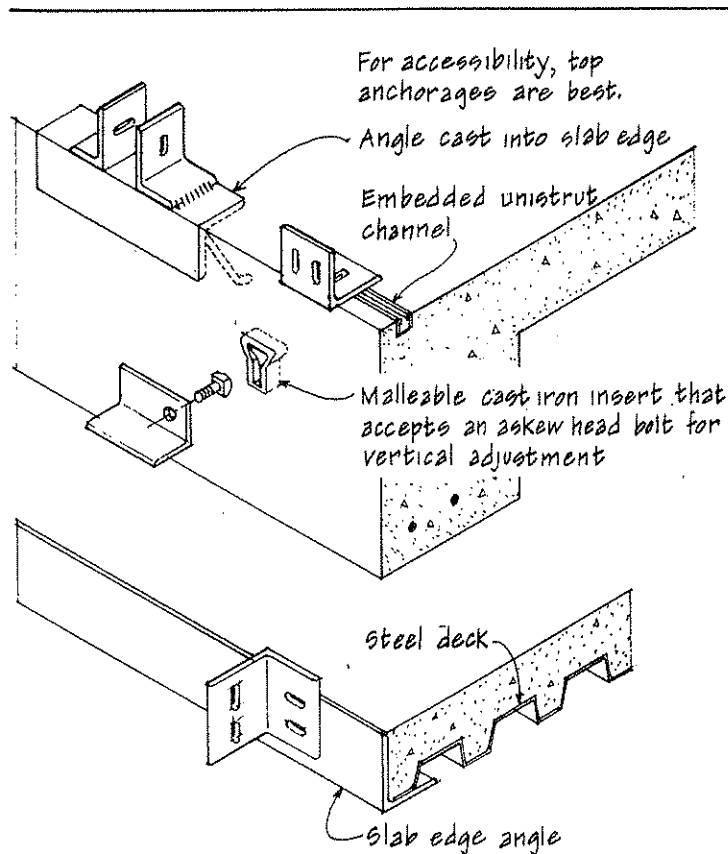
7.28 CURTAIN WALLS



A curtain wall is a nonbearing exterior enclosure which is supported by a building's structural steel or concrete frame. The wall may consist of preassembled panels or a metal framework which can hold either glass or opaque units. See 7.30 for an outline of these curtain wall types and materials.

While simple in theory, curtain wall construction is complex and requires careful development, testing, and erection. Close coordination is also required between the architect, engineer, contractor, and a fabricator who is experienced in curtain wall construction.

For more detailed information, refer to the Aluminum Curtain Wall Design Guide Manual, published by the American Architectural Manufacturers Association, Des Plaines, Illinois.



Some connections between the curtain wall and the building structure are fixed to resist loads applied from any direction. Others are movable and are designed to resist only lateral wind loads. These movable joints accommodate the differential movement between the wall and building frame. Differential movement can occur because of the building frame deflecting under loading or the curtain wall reacting to thermal stresses and changes in temperature.

ANCHORAGES

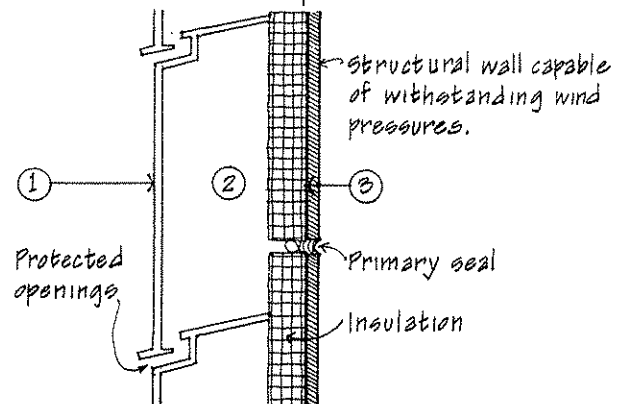
As with other exterior walls, a curtain wall must be able to withstand the following elements:

- WATER** Rain can collect on the wall surface and be wind-driven under pressure through the smallest openings. Water vapor that condenses and collects within the wall must be drained to the outside.
- WIND** Wind can create both positive and negative pressure on a wall, depending on its direction and the shape and height of the building. The wall must be able to transfer any wind loads to the building frame without deflecting too much. Wind-induced movement of the wall should be anticipated in the design of its joints and connections.
- SUN** Brightness and glare should be controlled with shading devices or the use of reflective or tinted glass. The sun's ultraviolet rays can also cause deterioration of joint and glazing materials and fading of interior furnishings.
- TEMPERATURE** Daily and seasonal variations cause expansion and contraction of a wall's material, especially metals. Joints and sealants must be able to withstand the movement caused by thermal stresses. Heat flow should be controlled by insulating opaque panels, using insulating glass, and incorporating thermal breaks into metal frames.
- LOADS** Any deflection or deformation of the building frame under loading should not be transferred to the wall. Seismic forces require the use of energy-absorbing connections.
- FIRE** A firestopping material must be installed at each floor within column covers and between the wall and the floor edge. Building codes also specify the fire resistance requirements for the wall itself.

BASIC FUNCTIONS

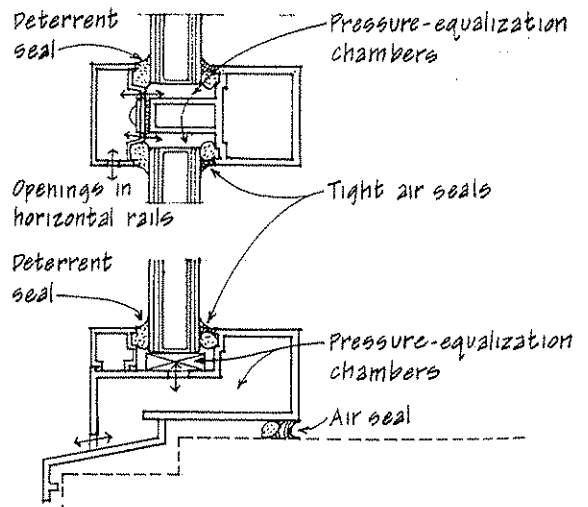
Pressure differential between inside and outside can cause water to leak through even the smallest openings in wall joints. Pressure-equalization design can significantly reduce this cause of water leakage. It requires three elements to be present:

- ① An exterior rain screen that deters water penetration.
- ② A confined air space that must be connected to the exterior so that its pressure is maintained equal to the outside pressure.
- ③ A continuous interior air and vapor barrier that seals the air space.



Air space should be segmented into relatively small areas with few openings, and be able to drain any water that enters to the outside.

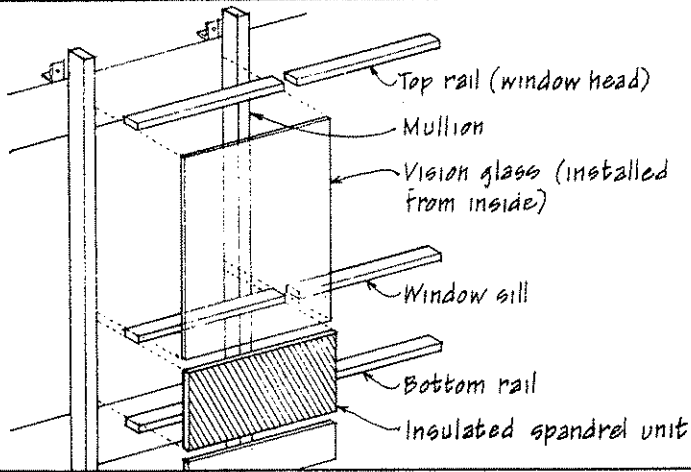
DIAGRAM



APPLICATION IN METAL CURTAIN WALL

PRESSURE-EQUALIZATION DESIGN

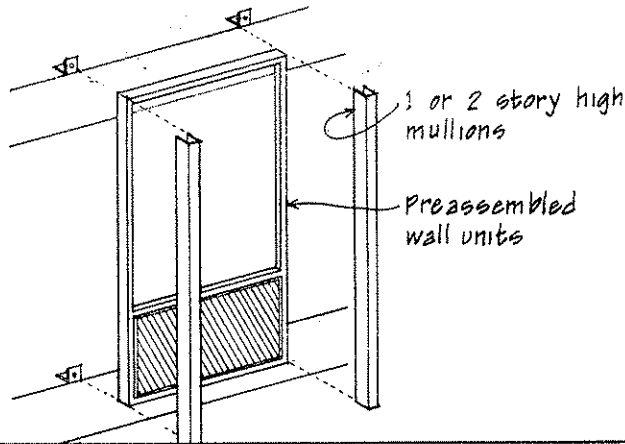
7.30 CURTAIN WALL TYPES



Curtain walls can first be categorized according to their method of assembly.

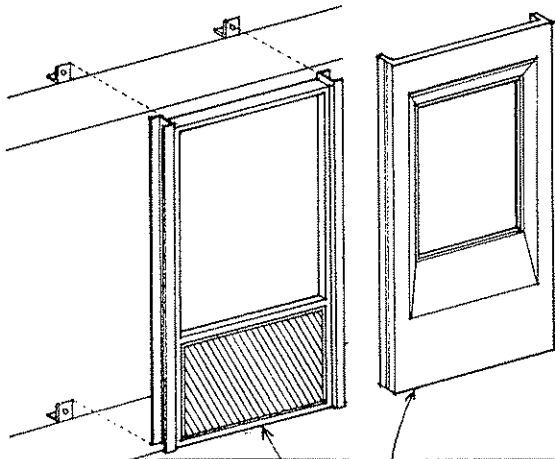
○ STICK SYSTEM

The stick system is assembled piece by piece. It offers relatively low shipping and handling costs and can be adjusted more readily than the other systems to on-site conditions.



○ UNIT AND MULLION SYSTEM

In this system, mullions are installed first. Pre-assembled panel units are then lowered into place behind the mullions. The panel units may be full-story height, pre-glazed or unglazed, or may be separate vision glass and spandrel units. Shipping bulk is greater than with the stick system, but less field labor and erection time is required.



○ PANEL SYSTEM

Panel systems consist entirely of large wall units, which may be either pre-assembled framed units or homogeneous panels. The wall units may be one, two, or three stories in height, and may be preglazed or glazed after installation. Panel systems offer controlled shop assembly and rapid erection, but are bulky to ship and handle.

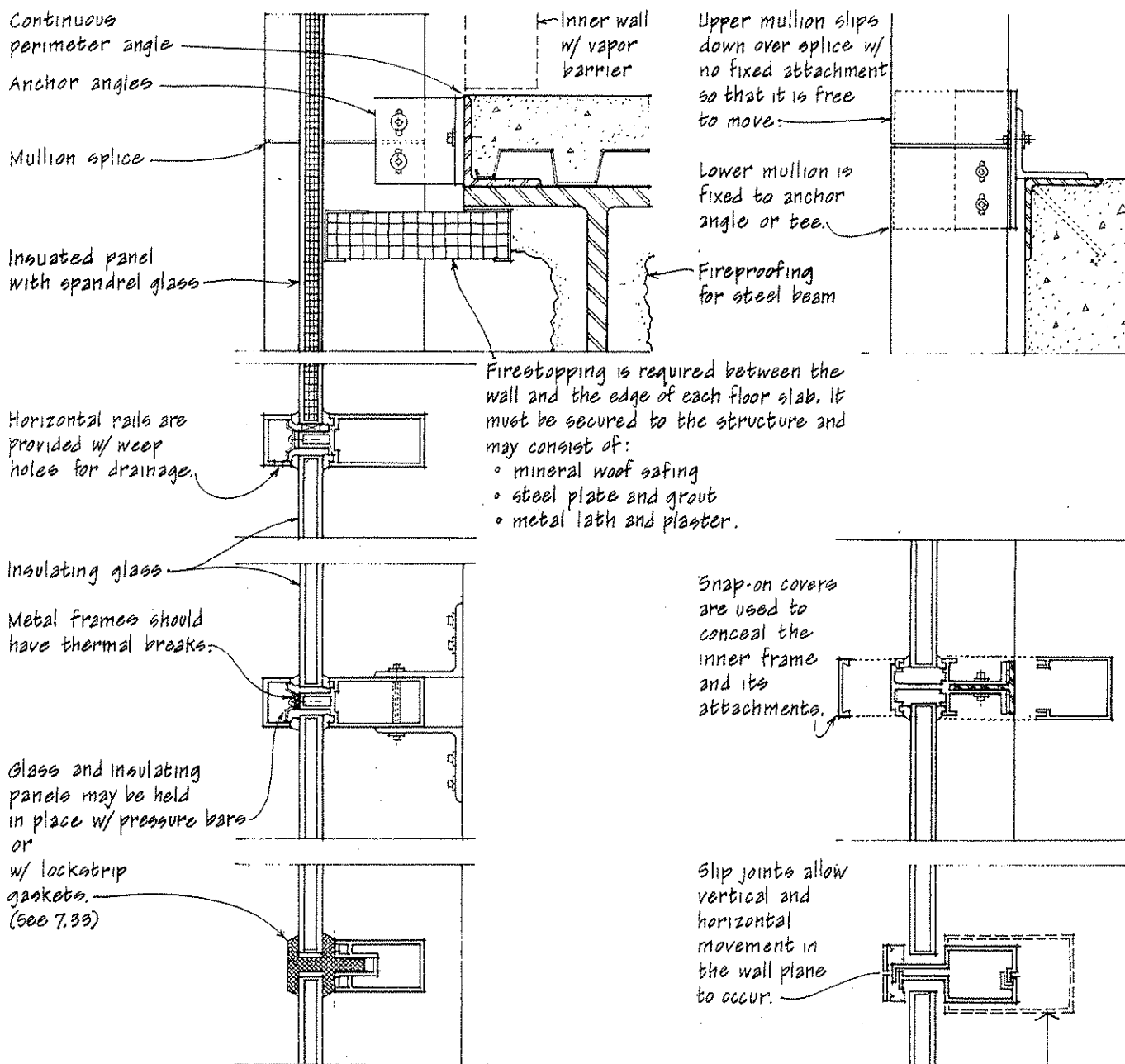
Wall panels:
Preassembled frame unit
Brick - 5.28
Stone - 5.36
Precast concrete - 5.48

Curtain systems can also be classified according to whether they are:

- Custom-designed specifically for a project.
- Assembled with parts and details which are standardized by the manufacturer.
- Composed of preformed sheet metal panels, typically for industrial-type buildings.

CURTAIN WALLS: DETAIL CONDITIONS

7.31



These metal and glass curtain wall details illustrate typical conditions only. When using standard fabricated wall systems, there is no need for extensive detailing except when components are modified. Things to note include:

- Overall wall pattern
- Type of glazing
- Type, size, and location of any operable windows
- Type and finish of infill panels
- Perimeter, corner, and anchorage conditions.

The required size, strength, and stiffness of the frame are determined by the loads the frame must carry—primarily lateral wind loads and relatively light vertical loads. Consult the manufacturer for the structural capacity of the wall's glazing and framing.

7.52

CURTAIN WALLS: DETAIL CONDITIONS

Unit or framed panel systems use split mullions which interlock.

Inside and outside joint covers are used if the split mullion consists of channel shapes.

Spacer gasket

Structural silicone sealant (See note below *)

silicone weatherseal w/ sealant backing

Insulating panel or glass

Mullion reinforcement

Insulating panels may have a facing of:

- Aluminum
- Stainless steel
- Porcelain enameled metal
- Ceramic tile in a plastic matrix
- Opaque tinted glass

Insulating core may be:

- Fiberglass
- Cellular glass
- Foamed plastic
- Polyethylene

Metal gravel stop and fascia

Structural steel support

Sealant

Bonded metal panel

Interlocking side joints

Sealant

Insulation

Insulated metal panels have inner and outer sheet metal facings sandwiching a layer of insulation.

Bonded metal panels may have honeycomb or urethane cores.

Girt

Sub-girt

Outer sheet

Inner sheet

Depth of ribs or flutes determines allowable span of panels

Sub-girt closure @ bottom

Steel base angle

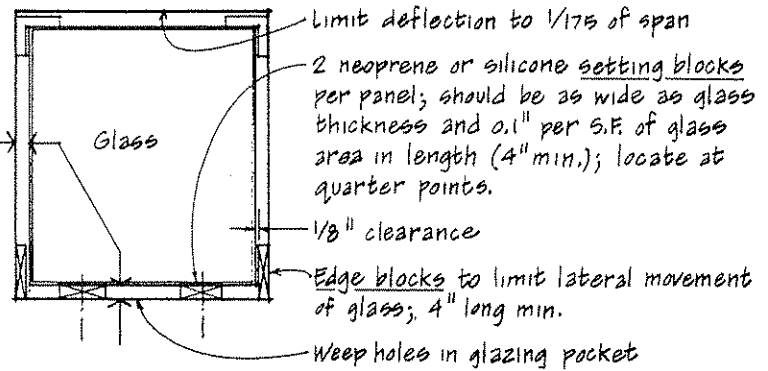
* Structural silicone sealant is a glazing system that transfers wind and other loads from the glass to the metal curtain wall frame without mechanical fastenings. The structural sealant must be compatible with both the glass units and the metal frame. The design should allow for easy maintenance and replacement of broken glass units. Factory-glazing is preferred for better quality control. Consult manufacturer for details.

Insulated and bonded metal panels are used primarily to clad industrial-type buildings. They may have facings of anodized aluminum or steel with porcelain, vinyl, acrylic, or enamel finishes. The panels span vertically between horizontal steel girts spaced 8' to 24' apart, depending on the type of panel used. Consult manufacturer for sizes, spans, thermal ratings, and installation details.

GLAZING SYSTEMS

7.55

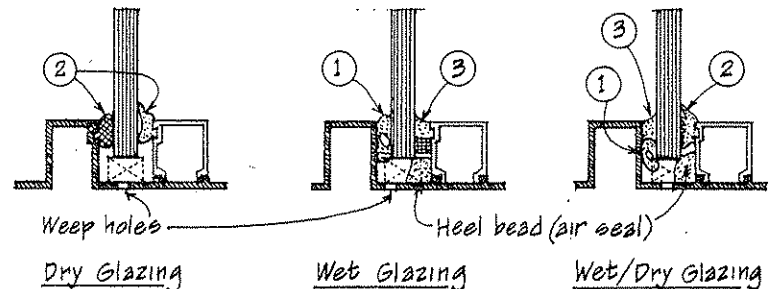
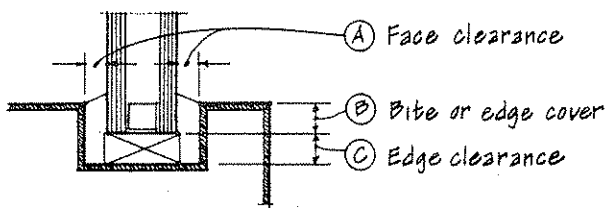
The glazing system should allow the glass unit to float in its opening and be cushioned with a resilient glazing material. There should be no direct contact between the glass and the perimeter frame. The perimeter frame itself must support the glass against wind pressure or suction, and be strong enough that structural movements and thermal stresses are not transferred to the glass.



GLAZING MATERIALS

Small lights may be glazed using glazier's points and a glazing compound, or for wood frames, a wood stop. Large lights (more than 6 S.F. in area) may be glazed with:

- ① Preformed butyl or polyisobutylene tape
- ② Compression gaskets of neoprene or silicone
- ③ Liquid high-range sealant of silicone or polyurethane



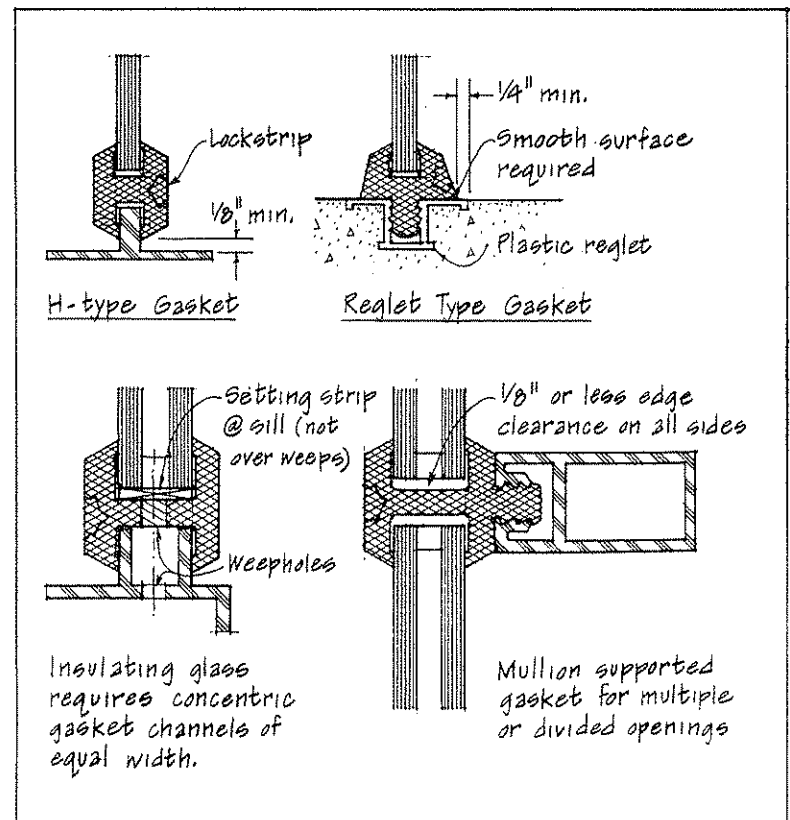
BITE, EDGE, AND FACE CLEARANCES

Glass Type		(A)	(B)	(C)
Sheet glass	SS	$1/16$ "	$1/4$ "	$1/8$ "
	DS	$1/8$ "	$1/4$ "	$1/8$ "
Plate glass	$1/4$ "	$1/8$ "	$3/8$ "	$1/4$ "
	$3/8$ "	$3/16$ "	$7/16$ "	$5/16$ "
	$1/2$ "	$1/4$ "	$7/16$ "	$3/8$ "
Insulating glass	$1/2$ "	$1/8$ "	$1/2$ "	$1/8$ "
	$5/8$ "	$1/8$ "	$1/2$ "	$1/8$ "
	$3/4$ "	$3/16$ "	$1/2$ "	$1/4$ "
	1"	$3/16$ "	$1/2$ "	$1/4$ "

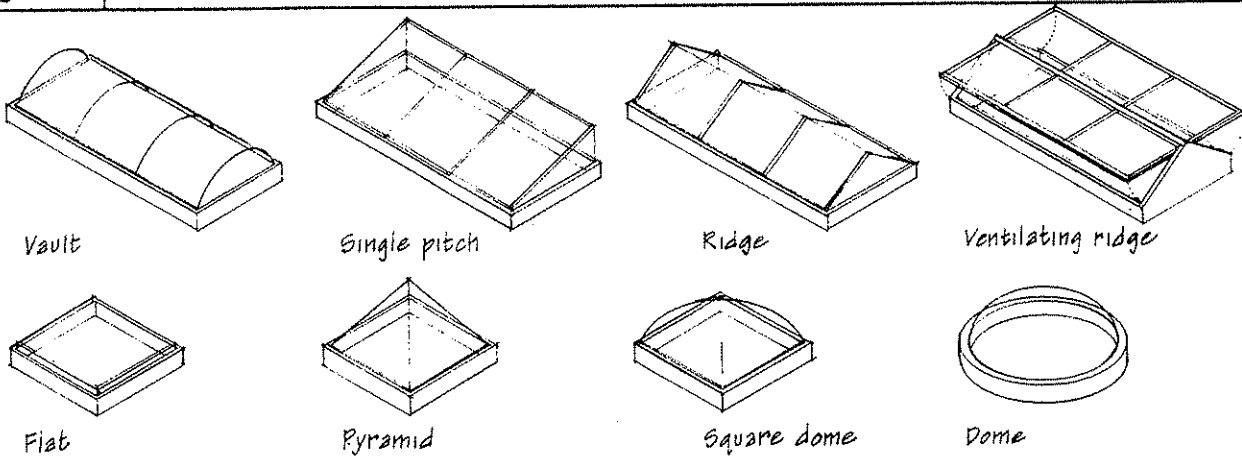
Heat-strengthened and tempered glass may require additional face clearance.

LOCKSTRIP GASKETS

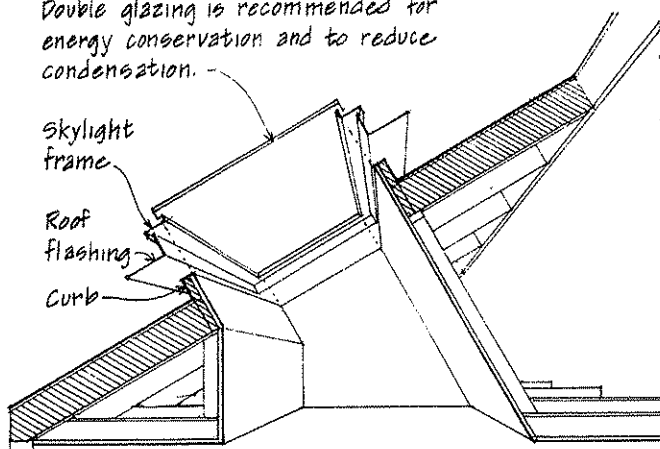
Structural gaskets are preformed of neoprene or other elastomeric material. They require smooth contact surfaces and a frame or opening with exacting dimensional tolerances and true plane alignment. The glass must be supported on at least two sides by the frame or a supported gasket.



7.54 SKYLIGHTS



Double glazing is recommended for energy conservation and to reduce condensation.



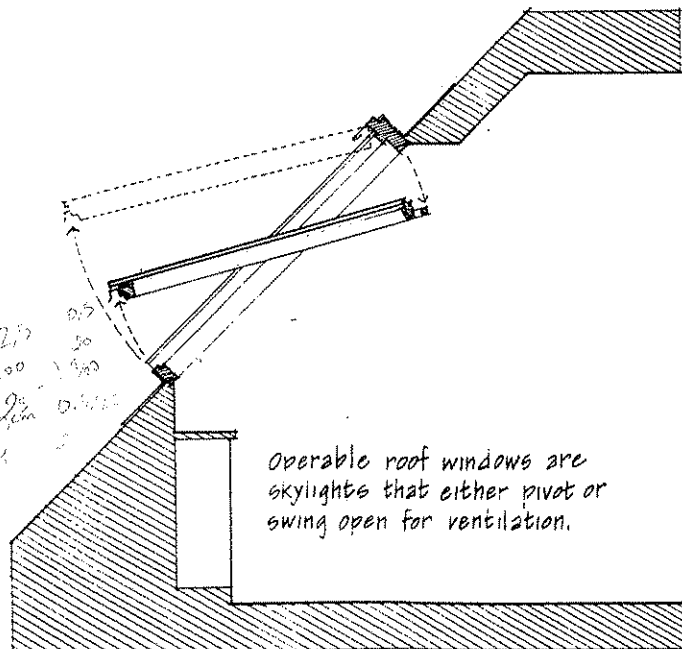
Skylights provide daylight for interior spaces from above. This daylighting can be in place of or in addition to normal daylighting from windows. Careful consideration should be paid to the control of brightness and glare, which may require the use of louvers, shades, or reflector panels. Horizontal and south-facing skylights also increase solar heat gain in the winter, but in the summer, shading may again be required to prevent excessive heat gain.

Skylights require a framed roof opening with a curb at least 4" high. This curb may be job-built or be an integral part of the skylight unit. The skylight unit itself must be able to carry the normal roof loads.

Skylights are available as preassembled units, complete with a wood or metal frame, glazing, and flashing, in stock sizes and shapes. (See illustration above.)

The glazing may be of plastic (acrylic or polycarbonate) or of glass. Building codes usually require the use of wire, laminated, or tempered glass, and limit the spacing of their supports to:

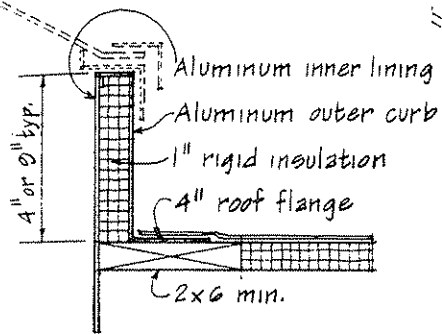
- Flat wired glass - 25"
- Corrugated wire glass - 60"
- Laminated glass - 48"
- Tempered glass - 72"



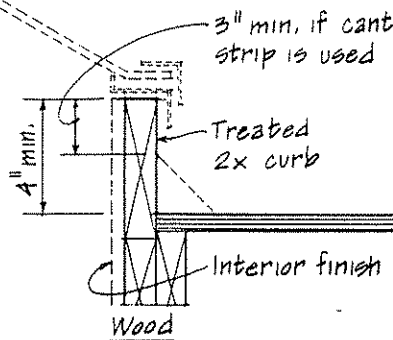
The minimum slope for flat or corrugated plastic skylights is 4:12. Plastic domes should rise at least 10% of the span or at least 5".

SKYLIGHT DETAILS

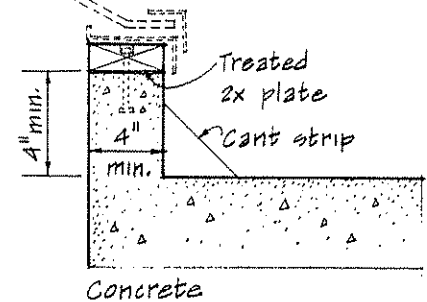
7.55



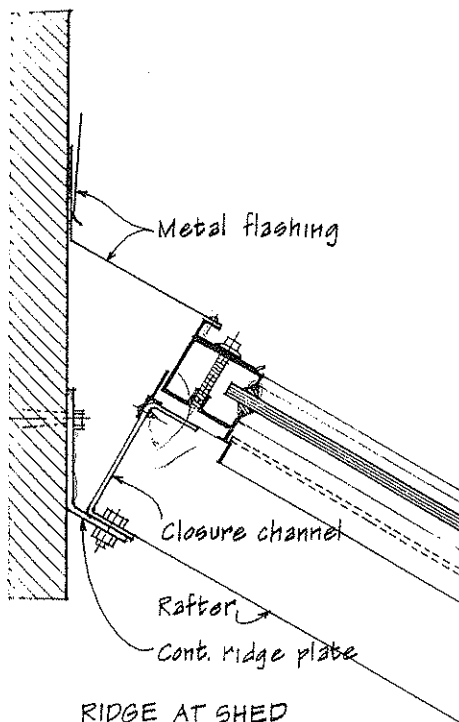
Aluminum
CURB TYPES



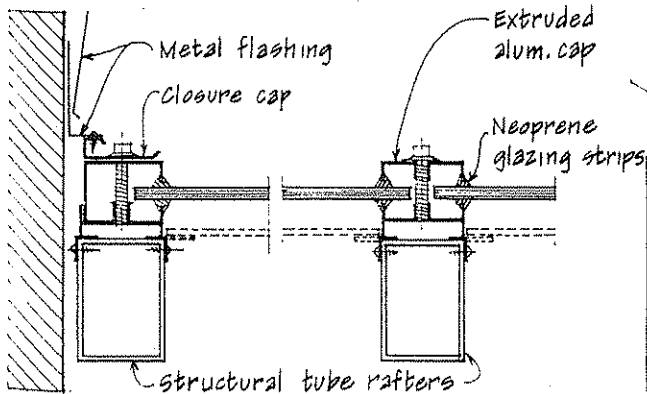
Wood



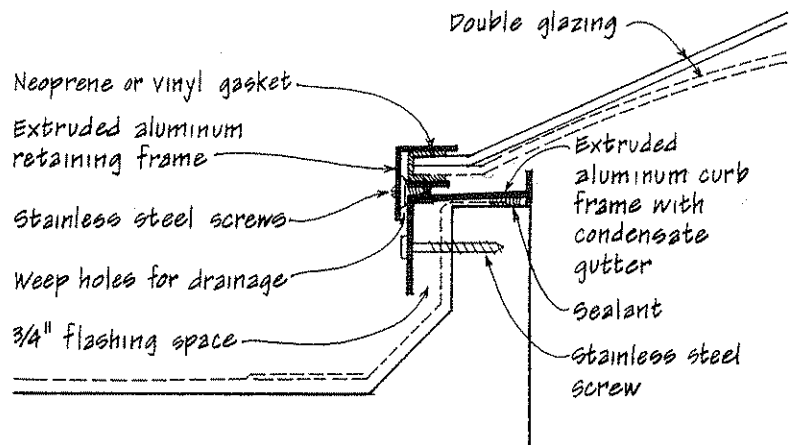
Concrete



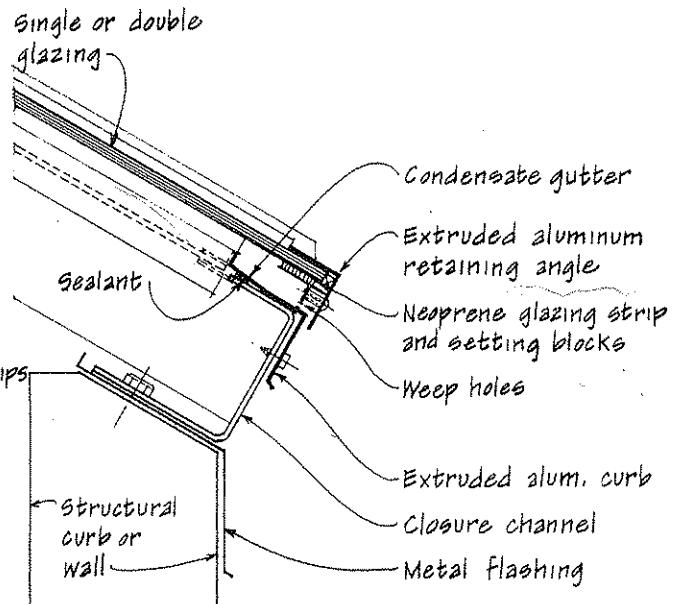
RIDGE AT SHED



END WALL AND RAFTER

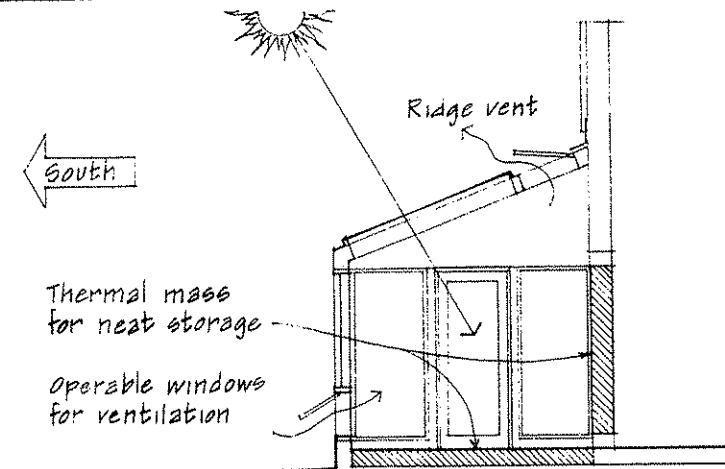


TYPICAL CURB DETAIL

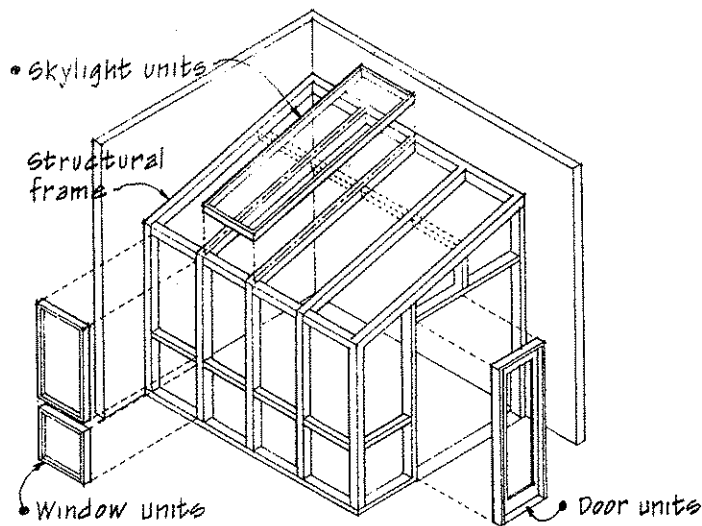


SILL OR EAVE

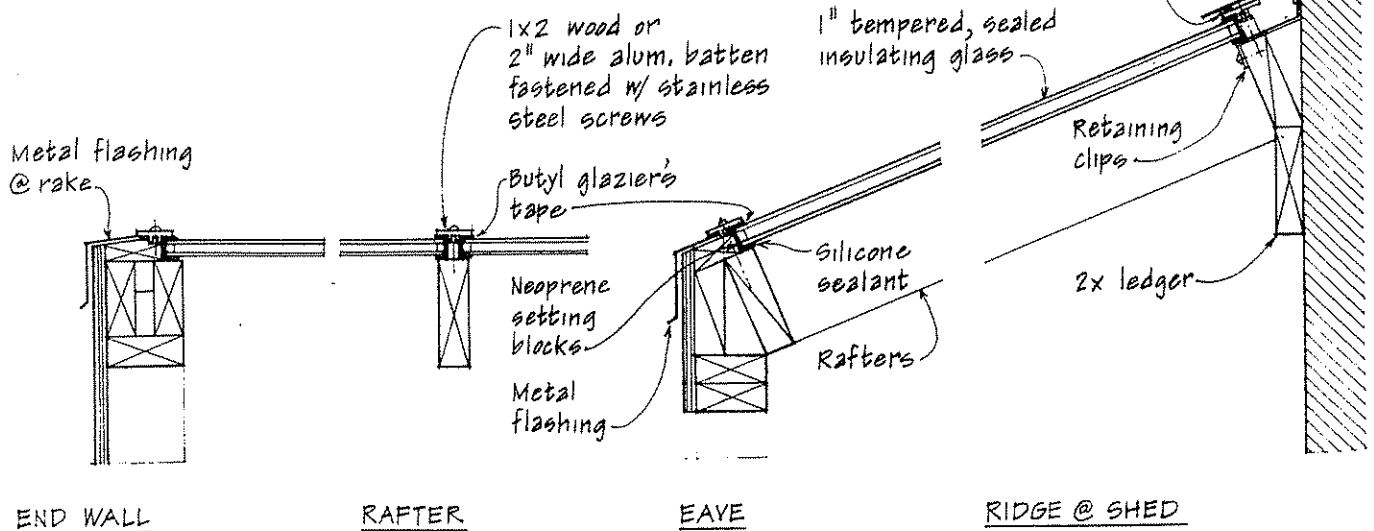
7.56 SUNSPACES



A sunspace can be a solarium adjoining another living space or be an attached greenhouse. It is often used in passive solar design in conjunction with a thermal mass of masonry, rock, or concrete to store the solar heat gain. Because of the possibility of overheating, provision should be made for shading and ventilation with operable windows and, if necessary, an exhaust fan.



Sunspaces and greenhouses are available as manufactured systems with wood or metal frames, complete with glazing, flashing, and accessories such as shades, blinds, and exhaust fans. A sunspace can also be constructed with standard window, door, and skylight units supported by a stud and rafter or a post and beam structural frame.



MOISTURE & THERMAL PROTECTION

8

Roofing materials provide the water-resistant covering for a roof system. They range in form from virtually continuous, impervious membranes to fabrics of overlapping or interlocking pieces of material. The type of finish roofing that may be used depends on the form of the roof structure, the roof pitch, and the appearance desired. While a sloping roof easily sheds water, a flat roof must depend on a continuous water-proof membrane to contain the water while it drains or evaporates. A flat roof (and any well-insulated sloped roof capable of retaining snow) should therefore be designed to support a greater live load than a moderately or high-pitched roof. Additional factors to consider in the selection of a roofing material include installation and maintenance requirements, durability, degree of wind and fire resistance required, and the roofing's color, texture, and pattern.

Flashing is required along roof edges, where roofs change slope or abut vertical planes, and where roofs are penetrated by chimneys, vent pipes, and skylights. Flashing materials must be installed to prevent leakage of water into the roof construction and eventually the interior of a building. Exterior walls must also be flashed where leakage might occur—at door and window openings and along joints where materials meet in the wall plane.

A waterproof membrane, fabric, or coating must be applied to those floors and walls below grade where water may be present in sufficient quantity or under sufficient pressure to cause leakage into a building's interior.

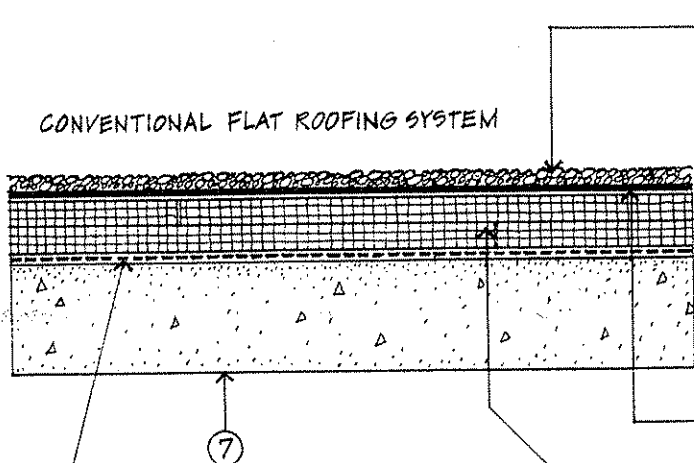
Moisture is normally present in a building's interior in the form of water vapor. When this water vapor reaches a surface cooled by heat loss to the cold outside air, condensation may occur. This condensation may be visible, as on an uninsulated window pane, or it can collect in concealed roof, wall, or floor spaces. Means of combating condensation include the correct placement of insulation and vapor barriers, and the ventilation of concealed spaces such as attics and crawl spaces.

Building materials expand and contract due to variations within the normal temperature range, as well as exposure to solar radiation and wind. To allow for this movement and help relieve the stresses caused by a material's expansion and contraction, expansion joints should be flexible, weathertight, durable, and correctly placed to be effective.

Potential heat loss or gain through a building's exterior enclosure is an important factor when estimating the amount of mechanical equipment and energy required to maintain the desired level of environmental comfort in a building's interior. The proper selection of building materials, the correct construction and insulation of a building's enclosure, and the orientation of a building on its site are the basic means of controlling heat loss and gain.

8.2 FLAT ROOF ASSEMBLIES

CONVENTIONAL FLAT ROOFING SYSTEM



① The WEAR COURSE protects the roofing from mechanical abrasion. It may be provided by built-up roofing aggregate, ballast aggregate, or plaza deck pavers.

② The DRAINAGE LAYER permits the free flow of water to the roof drains. It may consist of the aggregate layer in a built-up roofing system, the ballast layer in a loose-laid single-ply roofing system, the surface of a fully adhered single-ply roof, or the drainage fabric or space under the pavers in a plaza deck system.

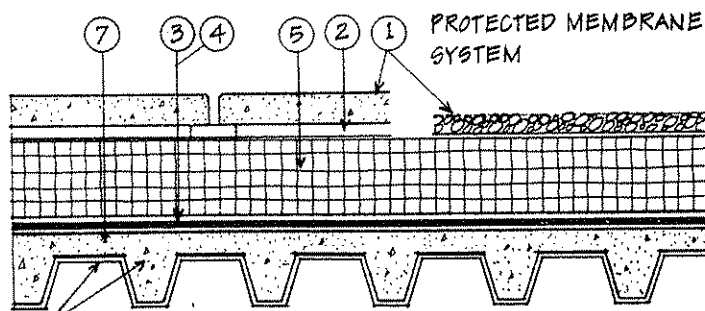
③ The ROOFING MEMBRANE is the waterproofing layer of the roof. It should be sloped $\frac{1}{4}$ " per foot to transport stormwater to the roof drains. Two major membrane systems are:

- Built-up roofing systems
- Single-ply roofing systems

④ A VAPOR BARRIER reduces the diffusion of moisture into the insulation layer of the roofing assembly. It should be installed when the average outdoor temperature in January is below 40°F . and the winter, interior relative humidity is 45% or greater at 68°F . The barrier may be in the form of asphalt-saturated roofing felt, or a proprietary material of low permeance.

When a vapor barrier is present, the insulation layer may have to be vented to allow vapor pressure to escape from between the vapor barrier and the roofing membrane.

⑤ THERMAL INSULATION provides the required resistance to heat flow through the roof assembly. It is usually installed under the roofing membrane in the form of a lightweight concrete fill or rigid insulation panels. Rigid insulation should be installed in at least two staggered layers to minimize heat loss through the joints. The first layer should be mechanically fastened to resist wind uplift; the upper layers are fully adhered with hot steep asphalt. When rigid plastic foam insulation (polyurethane, polystyrene, or polyisocyanurate) is used, the top layer should be perlite or gypsum board to provide a stable underlayment for the roofing membrane and to comply with code requirements.



PROTECTED MEMBRANE SYSTEM

⑥ An AIR BARRIER can help prevent moist indoor air from penetrating the roof assembly. It must be airtight and rigid enough to withstand wind pressure as well as pressure from below.

Both vapor and air barriers should be continuous, sealed at all roof penetrations, and tied into the wall assembly around the perimeter of the roof.

Thermal insulation can, in some cases, be placed under the roof deck or over the roofing membrane. See drawing to the left. In this inverted system, the insulation layer protects the roofing membrane from sunlight and temperature extremes, but not from almost continual dampness. Moisture-resistant polystyrene is required for the insulating layer.

⑦ The ROOF DECK must be stiff enough to maintain the desired slope under expected loading conditions, and be smooth, clean, and dry enough for the rigid insulation or roofing membrane to adhere properly. See table on next page for roof deck types. Large roof areas may require expansion joints or area dividers. For these and other FLASHING DETAILS, see 8.15.

BUILT-UP ROOFING SYSTEMS

§.5

Roof deck
(See table below)

Vapor barrier
(if required)

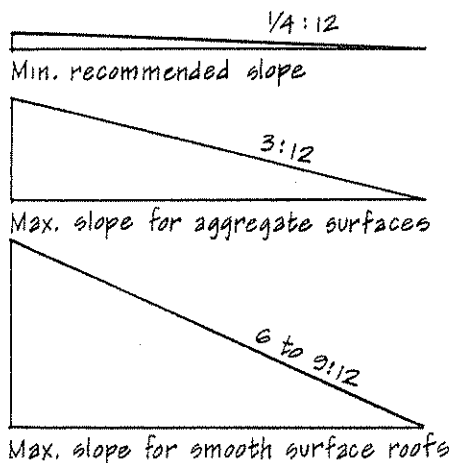
Thermal insulation
in at least two
staggered layers

Base sheet
of glass fiber (2" lap)
organic base felt (4" lap)

Plysheets
of fiberglass, asphalt saturated
felt, or coal tar saturated felt
placed with hot steep asphalt
or coal tar bitumen.

Wear course of
gravel, slag, or white
marble chips aids in
stiffening membrane and
resisting wind blowoff.

Surfacing bitumen
of coal tar or
asphalt



For slopes over 1:12,
lay plies parallel to
slope and back nail
to prevent slippage;
provide non-nailable
decks with treated
wood nailers for back
nailing.

Felt overlap for 2 ply roofing: 19"
3 ply roofing: 24 3/8"
4 ply roofing: 27 1/2"

TYPES OF ROOF DECKS OR SUBSTRATES

Consult roofing manufacturer for:

- Approved types of deck, insulation, and fastenings
- Installation details, and vapor barrier/venting requirements
- Underwriters' Laboratories (UL) Fire-Hazard Classification of the roofing assembly.

Steel Deck	22 gauge min.; code may require overlayment of perlite or gypsum bd.
Wood	Min. 1" nominal thickness; of well-seasoned lumber; tongue and grooved or splined; cover knotholes and large cracks with sheet metal.
Plywood	Min. 1/2" thick; face plies perpendicular to supports spaced no more than 24" o.c.; tongue and groove joints or blocking under joints.
Structural Wood-Fiber Deck	Must be dense enough to hold mechanical fasteners.
Poured Concrete	Should be well-cured, dry, frost-free, smooth, and sloped to drain.
Precast Concrete	All joints should be grouted; any unevenness between units must be leveled with a vented topping or fill.
Lightweight Insulating Concrete...	Must be fully cured and air dried; consult manufacturer for acceptability.

§.4 SINGLE-PLY ROOFING SYSTEMS

Single-ply roofing may be applied in sheet or liquid form. Sheet materials used for single-ply roofing include:

- EPDM (ethylene propylene diene monomer), an elastomeric material.
- PVC (polyvinyl chloride), a thermoplastic material.
- CSPE (chlorosulfonated polyethylene), a synthetic rubber.
- Neoprene (polychloroprene), a synthetic rubber.
- Polymer-modified bitumens, a composite material.

These materials are thin (0.03 to 0.10 inches in thickness), flexible, and strong. They vary in their resistance to flame propagation, oils, chemicals, ultraviolet rays, pollutants, and abrasion. Some are reinforced with glass fiber or polyester; others have coatings for greater heat-reflectance or resistance to flame spread. Consult the roofing manufacturer for:

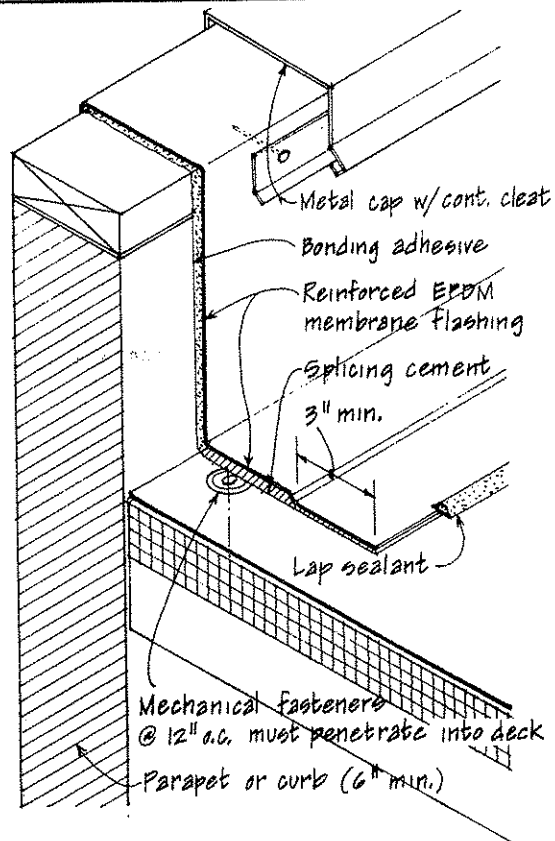
- Material specifications
- Approved types of roof deck, insulation, and fastenings
- Installation and flashing details
- Underwriters' Laboratories (UL) Fire-Hazard Classification of the roof assembly.

The details on this and the following page refer to EPDM roofing. Details for other single-ply membranes are similar in principle.

There are three generic systems for the application of EPDM roofing:

- ① Fully adhered system
- ② Mechanically fastened system
- ③ Loose laid, ballasted system

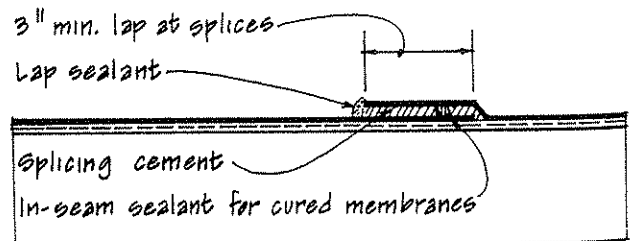
On large domed, vaulted, or complex roof forms, the roofing membrane may be rolled or sprayed on in liquid form. Materials used for liquid-applied membranes include silicone, neoprene, butyl rubber, and polyurethane. Consult manufacturer for details.

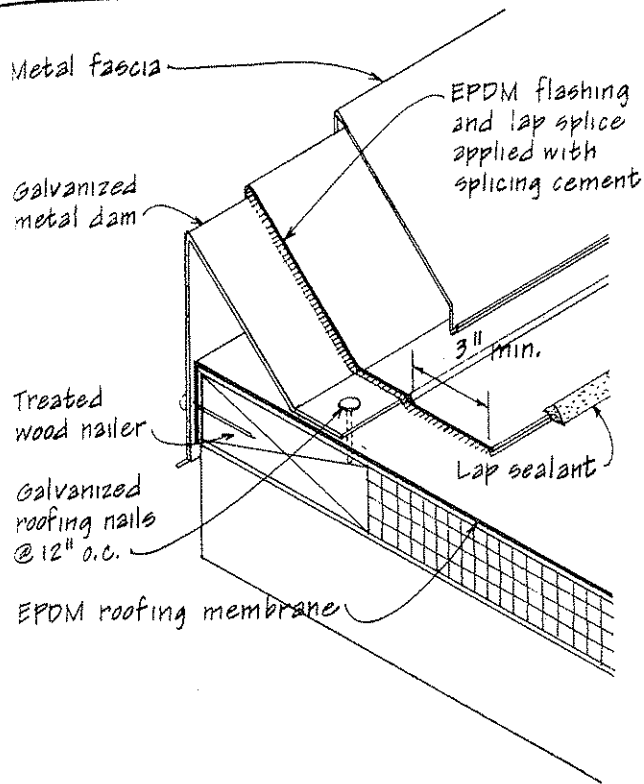


FULLY ADHERED SYSTEM

The membrane is fully adhered with bonding adhesive to a smooth surfaced concrete or wood deck, or to insulation that is mechanically fastened to the roof deck. Along the perimeter and at roof penetrations, the membrane is also mechanically fastened.

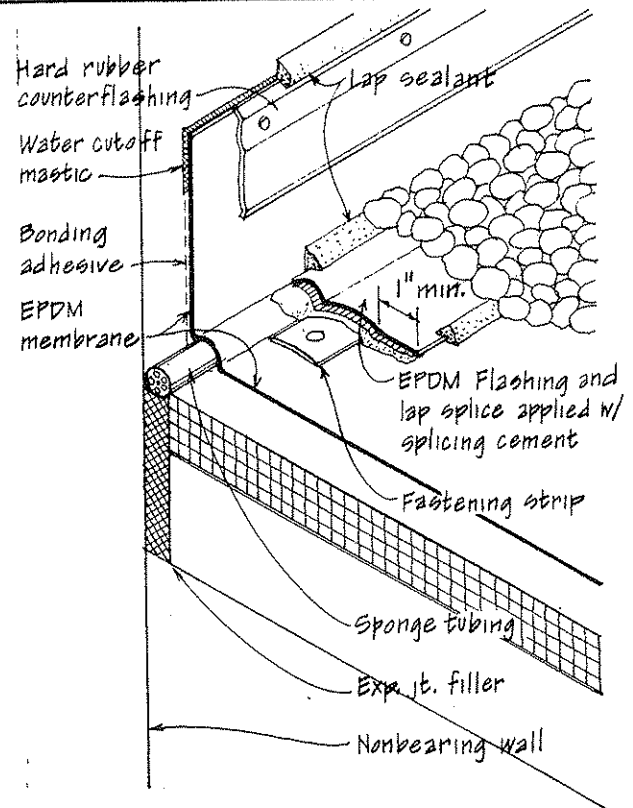
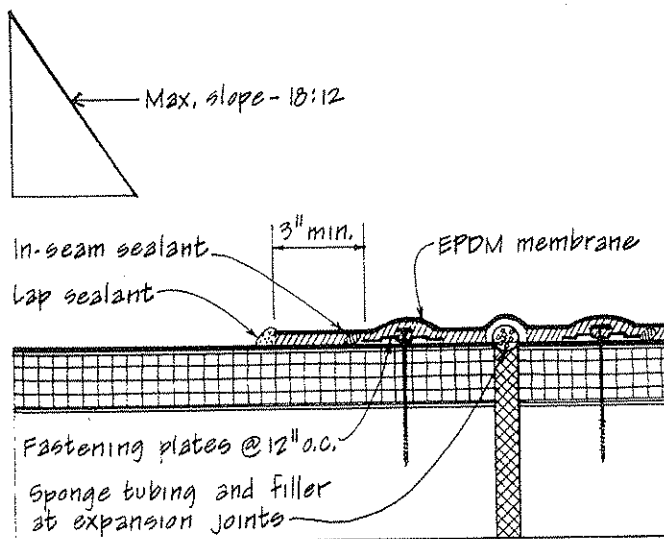
Since there is no slope limitation, this system can be used for complex or contoured roof forms.





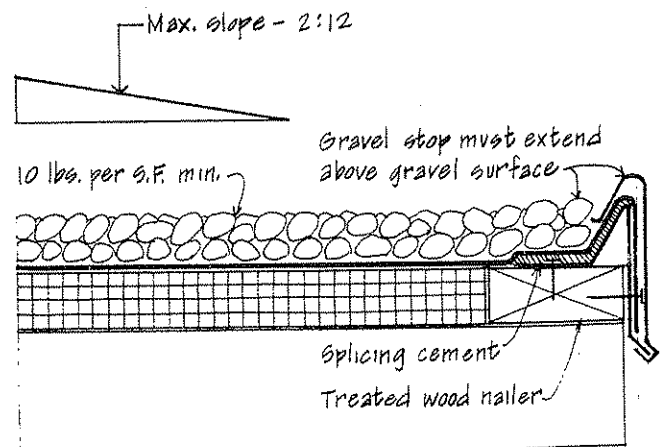
MECHANICALLY FASTENED SYSTEM

After insulation has been mechanically fastened to the roof deck, the membrane is also secured to the deck with plates and fasteners in the membrane splices.



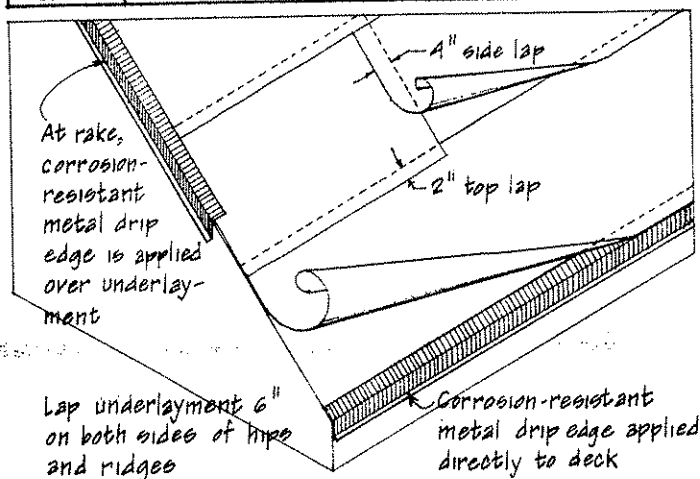
LOOSE LAID, BALLASTED SYSTEM

Both the insulation and the membrane are laid loosely over the roof deck, and secured with a layer of river-washed gravel or a roof paver system. Additional securement is provided with fasteners into the roof deck along the perimeter and at roof penetrations.



Deck must be able to carry additional weight of ballast.

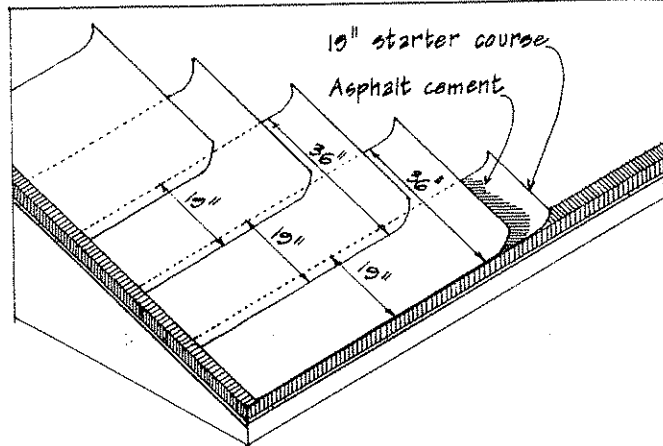
8.6 UNDERLAYMENT FOR SHINGLE ROOFING



UNDERLAYMENT FOR NORMAL SLOPES (4:12 and up)

Underlayment protects the roof sheathing from moisture absorption until the shingles are applied. Once the roofing is applied, the underlayment provides the sheathing with additional protection from wind-driven rain. The underlayment material should have low vapor resistance so that moisture does not accumulate between the underlayment and the roof sheathing. Only enough nails are used to hold the underlayment in place until the roofing shingles are applied.

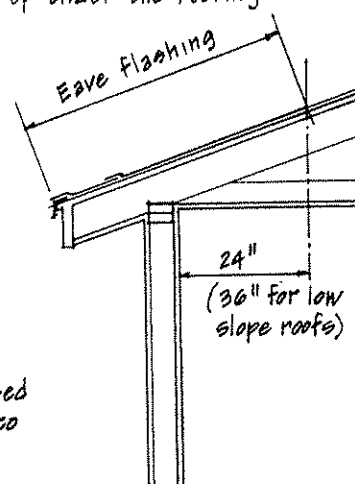
Drip edges of corrosion-resistant metal protect the roof edge and allow water to drip free of the roof edge. They may be omitted on wood shingle and shake roofs since the shingles themselves form drips by projecting beyond the roof edge.



UNDERLAYMENT FOR LOW SLOPE ROOFS (3:12-4:12)

EAVE FLASHING is recommended whenever there is a possibility that ice might form along the eave and cause water to back up under the roofing shingles.

On normal slope roofs, eave flashing consists of 15 lb. smooth roll roofing extending up the roof to a point 24" inside the interior wall line.

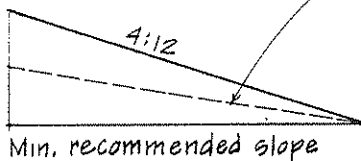
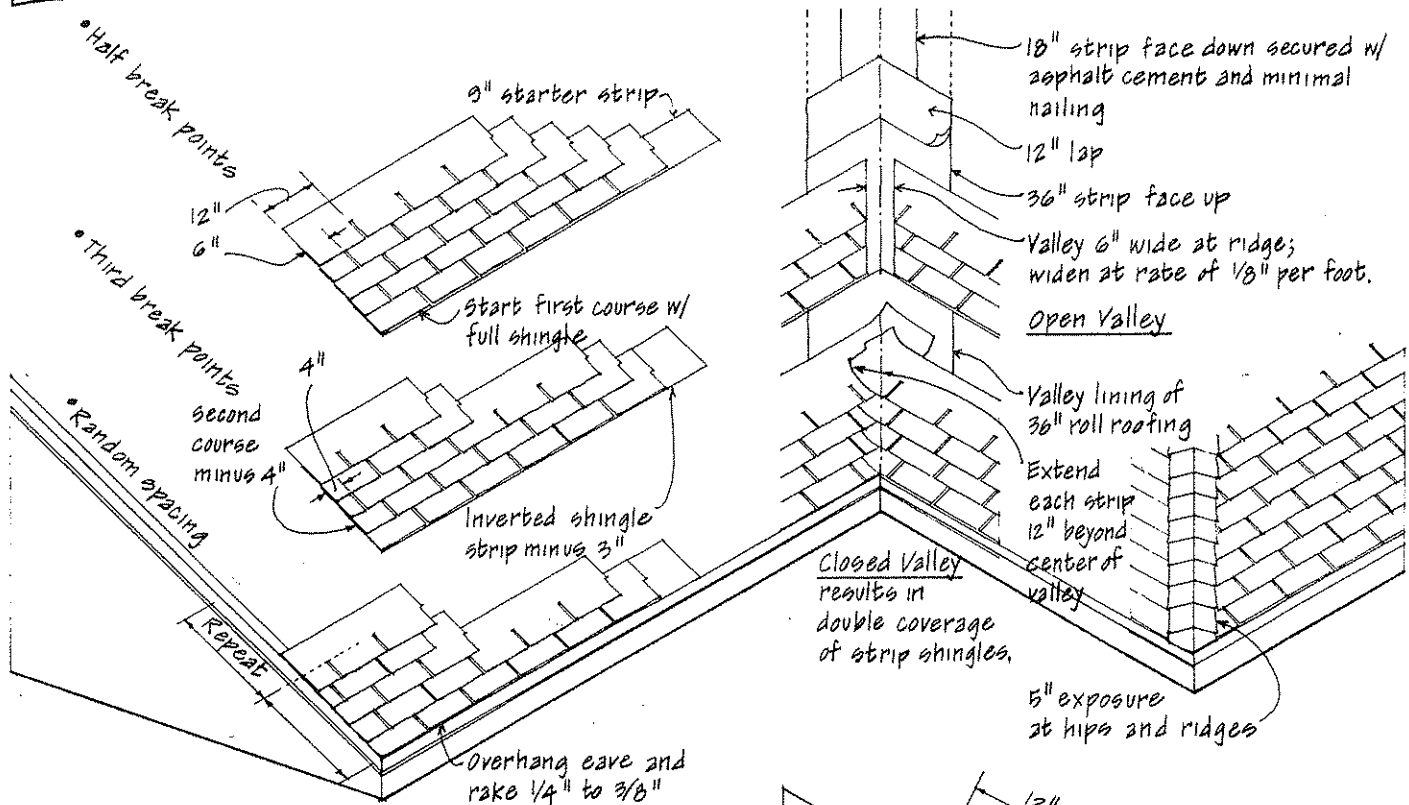


On low slope roofs, an additional course of underlayment is cemented in place, and extended to a point 36" inside the interior wall line.

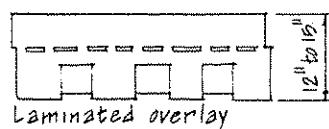
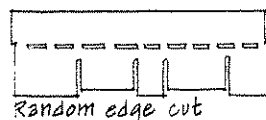
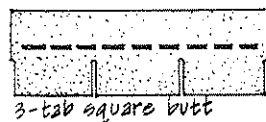
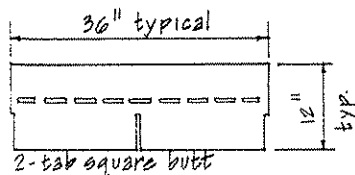
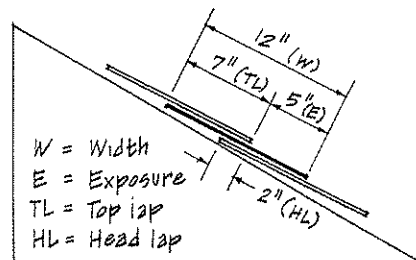
UNDERLAYMENT AND SHEATHING FOR SHINGLE ROOFS

Roofing Type	Sheathing	Underlayment	Normal Slope		Low Slope	
Fiberglass shingles	Solid	15 lb. asphalt saturated felt	4:12 and up	Single layer	3:12 to 4:12	Double layer
Asphalt shingles	Solid	15 lb. asphalt saturated felt	4:12 and up	Single layer	2:12 to 4:12	Double layer
Wood shakes	Spaced	30 lb. asphalt saturated felt (interlayment)	4:12 and up	Underlayment starter course; interlayment over entire roof	Not recommended	
	Solid	30 lb. asphalt saturated felt (interlayment)	4:12 and up	Underlayment starter course; interlayment over entire roof	3:12 to 4:12	Single layer underlayment and interlayment over entire roof
Wood shingles	Spaced	Not required	5:12 and up	Not required	3:12 to 5:12	Reduce weather exposure
	Solid (to minimize air infiltration)	15 lb. asphalt saturated felt	5:12 and up	Not required but may be desirable to protect sheathing	3:12 to 5:12	Not required but may be desirable to protect sheathing

FIBERGLASS AND ASPHALT SHINGLES



Wind resistant strip shingles may be laid on slopes as low as 2:12 if applied over a double layer of underlayment.



Fiberglass and asphalt shingles are similar in size, appearance, and application. Fiberglass shingles have an inorganic base that gives them excellent fire resistance (UL Class A). Asphalt shingles, having an organic felt base, possess only a moderate resistance to fire (UL Class C).

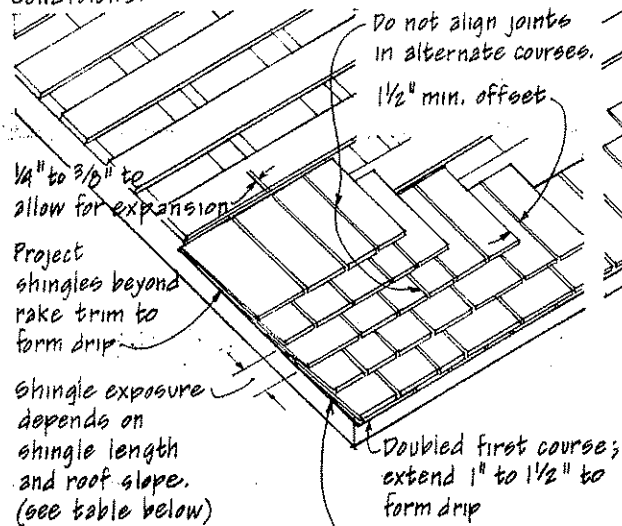
Most shingles have self-sealing adhesive or locking tabs that make them wind resistant. Wind resistance is important when shingles are used on low slope roofs and in areas subject to high winds.

Shingles vary in weight from 205 to 380 lbs. per square. (One square = 100 S.F.)

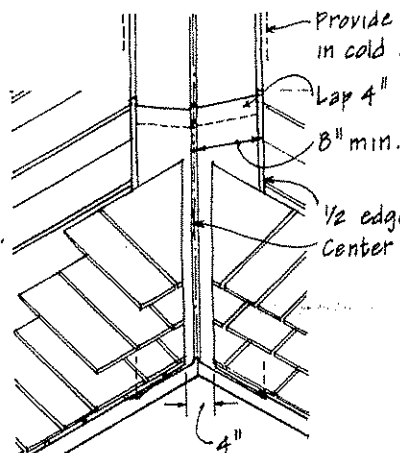
Consult the roofing manufacturer for sizes, patterns, colors, and installation details.

§.8 WOOD SHINGLE ROOFING

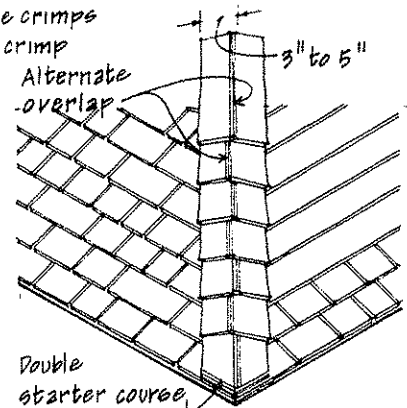
Spaced 1x4 or 1x6 sheathing provides ventilation for the shingles. Board spacing is equal to the shingle exposure. See table below. Solid sheathing sheathing may be desirable in areas subject to blizzard conditions.



In cold climates, eave flashing over solid sheathing is required. It consists of a double layer of 15 lb. asphalt saturated felt, cemented on slopes below 4:12.

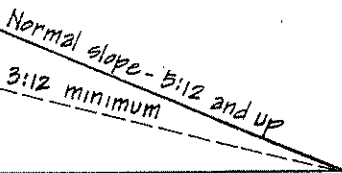


OPEN VALLEY
Flashing to be aluminum or 26 ga. min. galv. iron. Do not use copper with red cedar.



HIP APPLICATION (Ridge similar)

* Use only corrosion-resistant nails, such as hot-dipped galvanized steel or aluminum. Nails should be driven flush with, but not into the surface of the shingles.



MAXIMUM RECOMMENDED EXPOSURE

Shingle grade and length	Roof slope:	
	4:12 and up	3:12 to 4:12
N# 1 16"	5"	3 3/4"
18"	5 1/2"	4 1/4"
24"	7 1/2"	5 3/4"
N# 2 16"	4"	3 1/2"
18"	4 1/2"	4"
24"	6 1/2"	5 1/2"
N# 3 16"	3 1/2"	3"
18"	4"	3 1/2"
24"	5 1/2"	5"
Wood Shakes 18"	7 1/2"	Not recommended
24"	10"	

For wall siding applications of wood shingles and shakes, see 10.25.

Wood shingles and shakes are normally of red cedar, although white cedar and redwood shingles may be available. Red cedar has a fine, even grain and is naturally resistant to water, rot, and sunlight.

Red cedar shingles are available in 16", 18", and 24" lengths, and in the following grades:

N# 1 Premium Grade . . . 100% heartwood, 100% clear (Blue Label) 100% edge grain

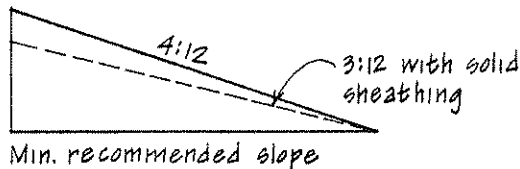
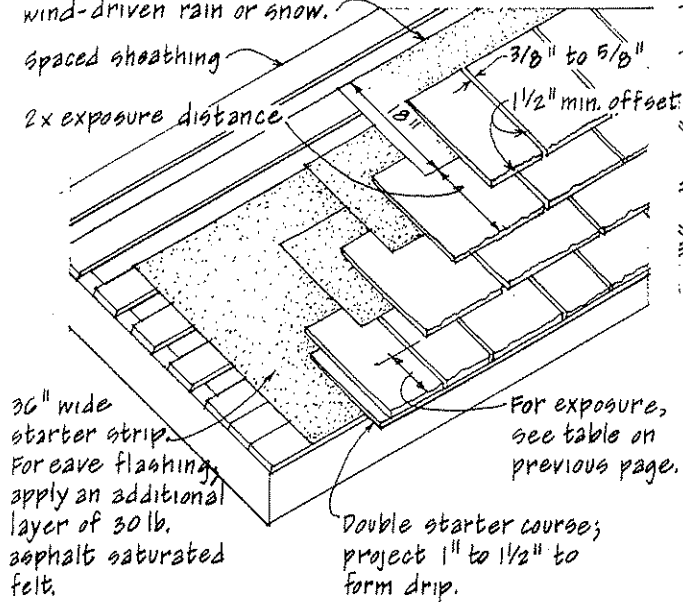
N# 2 Intermediate Grade . . . 10" clear on 16" shingles (Red Label) 11" clear on 18" shingles 16" clear on 24" shingles

Some flat grain permitted

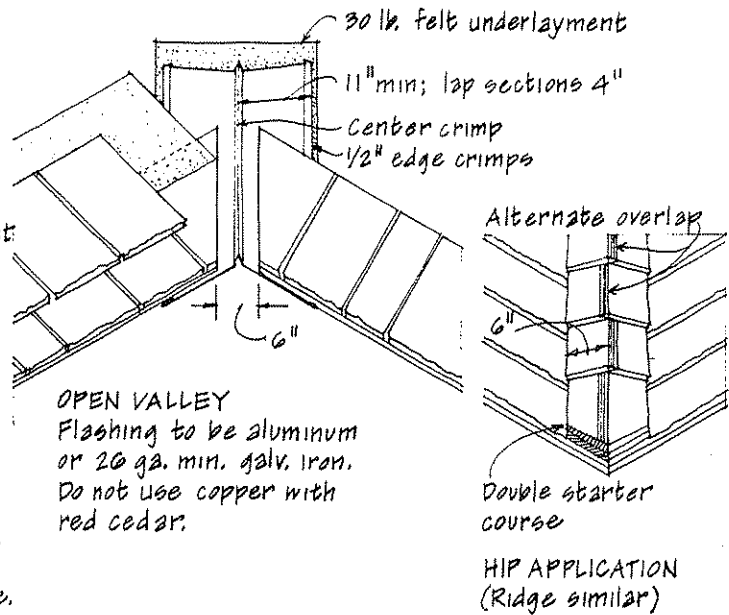
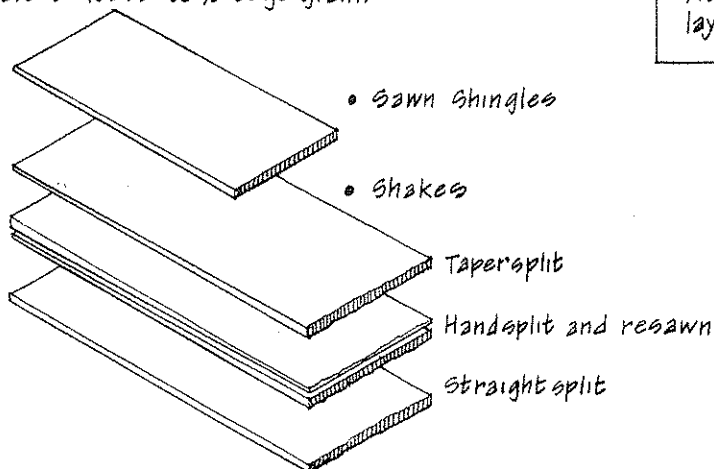
N# 3 Utility Grade 6" clear on 16" and 18" shingles (Black Label) 10" clear on 24" shingles

WOOD SHAKE ROOFING

Because of the rough texture of wood shakes, a layer of interlayment is laid between each course. The interlayment, 30 lb. asphalt saturated felt, serves as a baffle against wind-driven rain or snow.



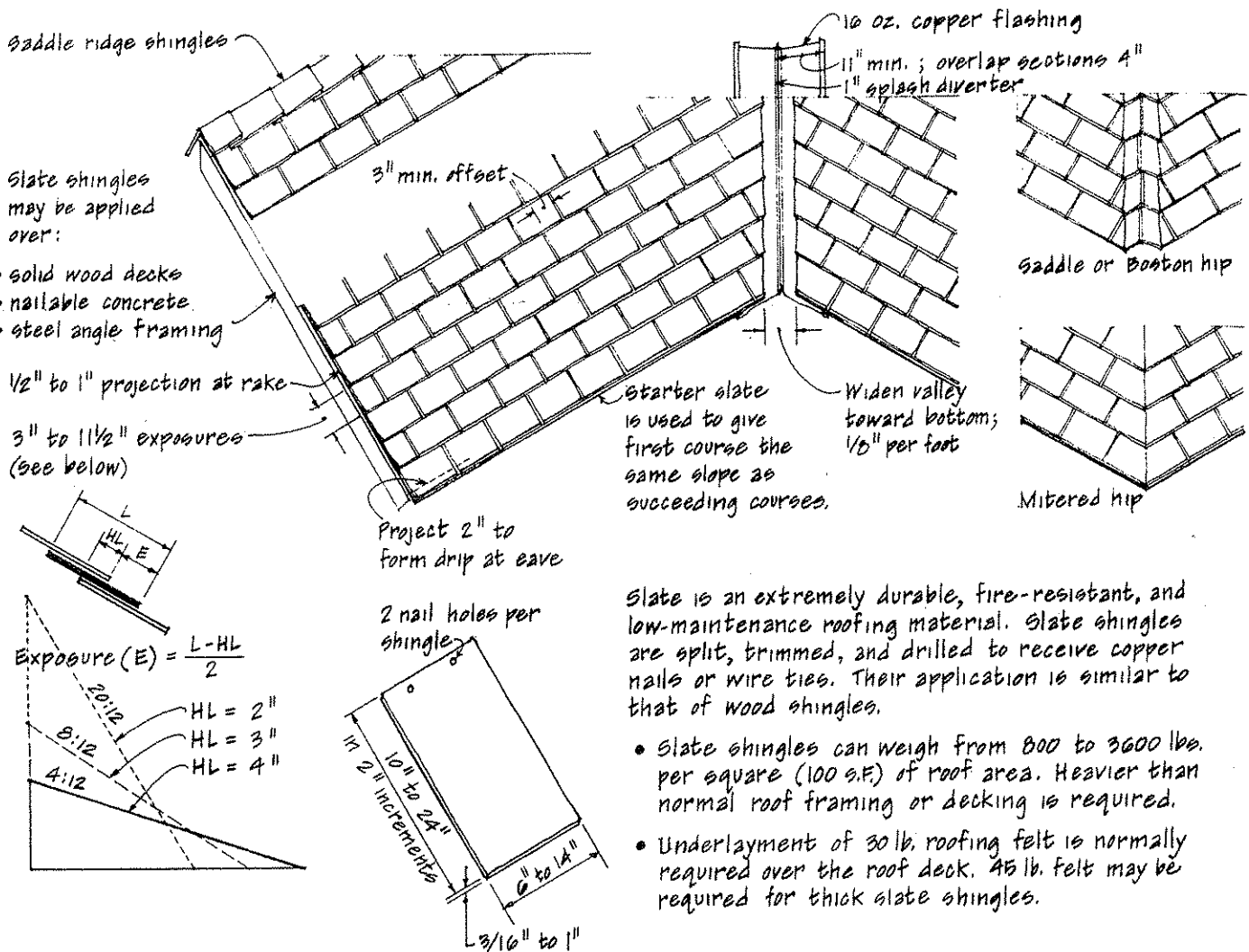
While wood shingles are sawn, wood shakes are split, resulting in at least one highly textured side. Shakes are normally 100% clear heart-wood, and available in 18" and 24" lengths. Tapersplit and straight-split shakes have 100% edge grain, while handsplit and resawn shakes have at least 90% edge grain.



* Use only corrosion-resistant nails, such as hot-dipped galvanized steel or aluminum. Nails should be driven flush with, but not into the surface of the shakes.

Wood shingles and shakes are flammable unless chemically treated to receive a UL Class C rating. A Class B rating may be possible if Class C shingles or shakes are used over a solid roof deck of 5/8" plywood (with exterior glue). Asbestos felt should be used for the underlayment and interlayment required.

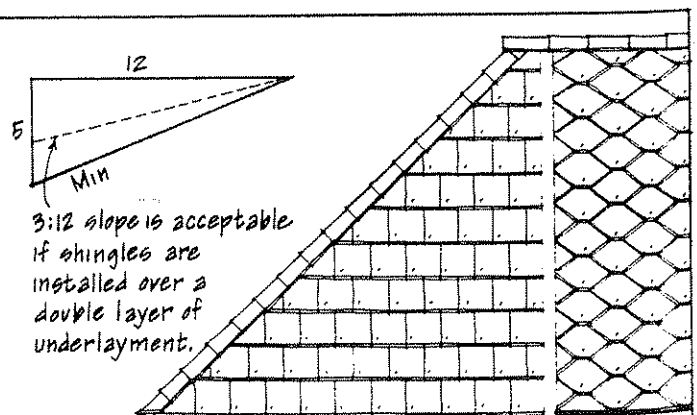
§.10 SLATE ROOFING



ASBESTOS-CEMENT SHINGLES

Asbestos-cement shingles are highly fire-resistant and have a texture resembling that of slate or wood shakes. In addition to the rectangular shingle shape of slate, other shapes have been developed to decrease the amount of material required to cover a given area. These include diamond, hexagonal, and Dutch lap shingles.

The individual shingles are predrilled for nailing. Because the shingles have only a small overlap, storm anchors or clips are used to hold the exposed edges of the shingles down. To simplify the application of the shingles, eave starter strips, hip and ridge shingles, and ridge rolls are available.

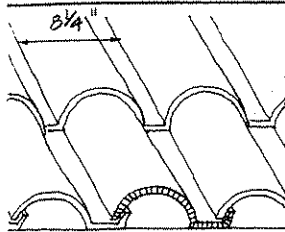
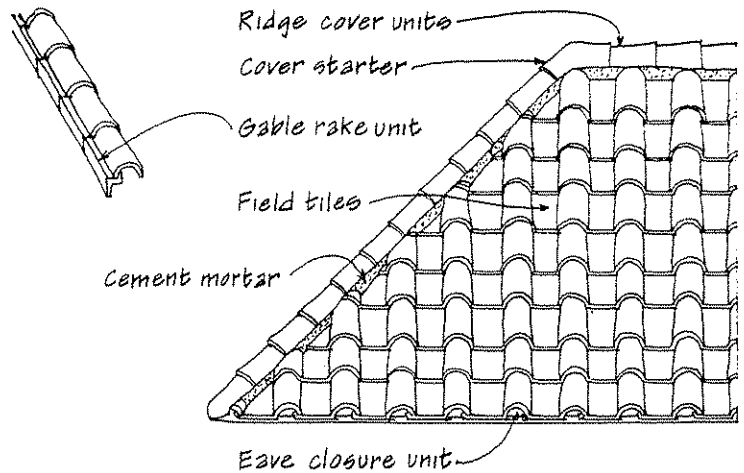


TILE ROOFING

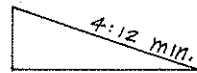
§.11

Tile roofing consists of clay or concrete units which overlap or interlock to create a strong textural pattern. Like slate, roofing tiles are fire resistant, durable, and require little maintenance. They are also heavy and require roof framing that is strong enough to carry the weight of the tiles.

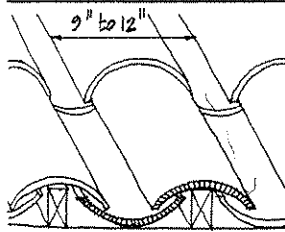
Roofing tiles are normally installed over a solid plywood deck with an underlayment of 30 lb. or 45 lb. roofing felt. Special tile units are used at ridges, hips, rakes, and eaves.



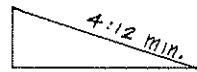
SPANISH



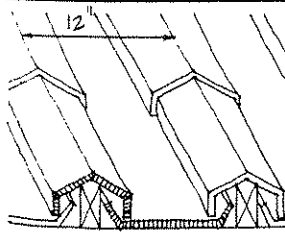
Length: $13\frac{1}{4}"$
Weight: 850-900 lbs./square
Exposure: $10\frac{1}{2}"$



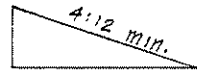
MISSION



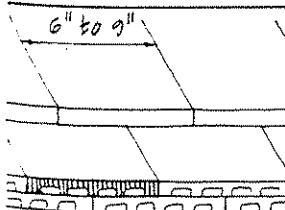
Length: 14" to 18"
Weight: 1250 lbs./square
Exposure: 11" to 15"



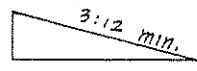
GREEK



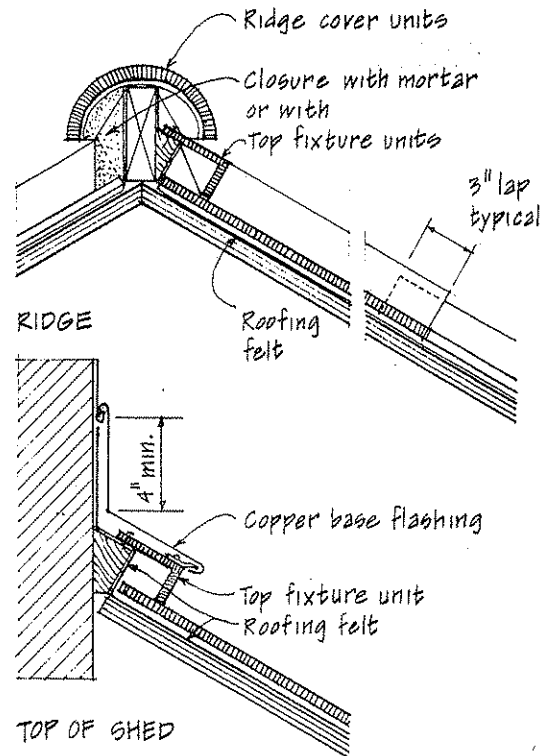
Length: $12\frac{3}{4}"$
Weight: 1250 lbs./square
Exposure: 10"



FLAT SHINGLE TILE

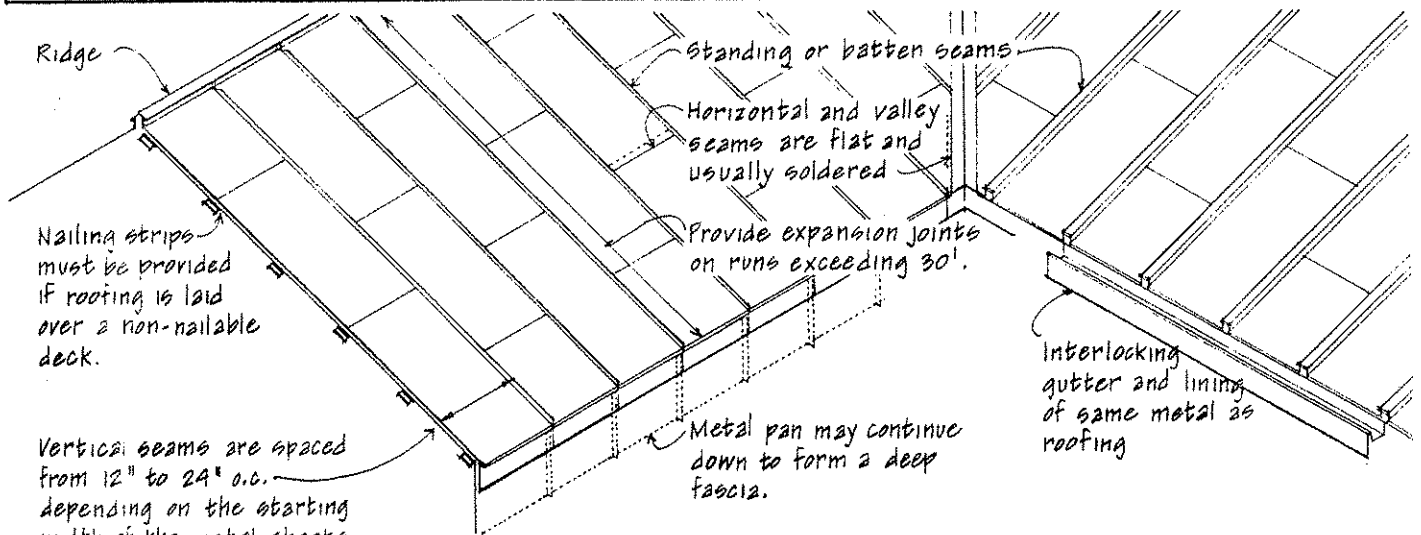


Length: 12" to 15"
Weight: 800-1200 lbs./square
Exposure: 9" to 12"



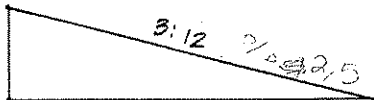
Confirm sizes, weights, and installation details with tile manufacturer.

§.12 SEAMED METAL ROOFING

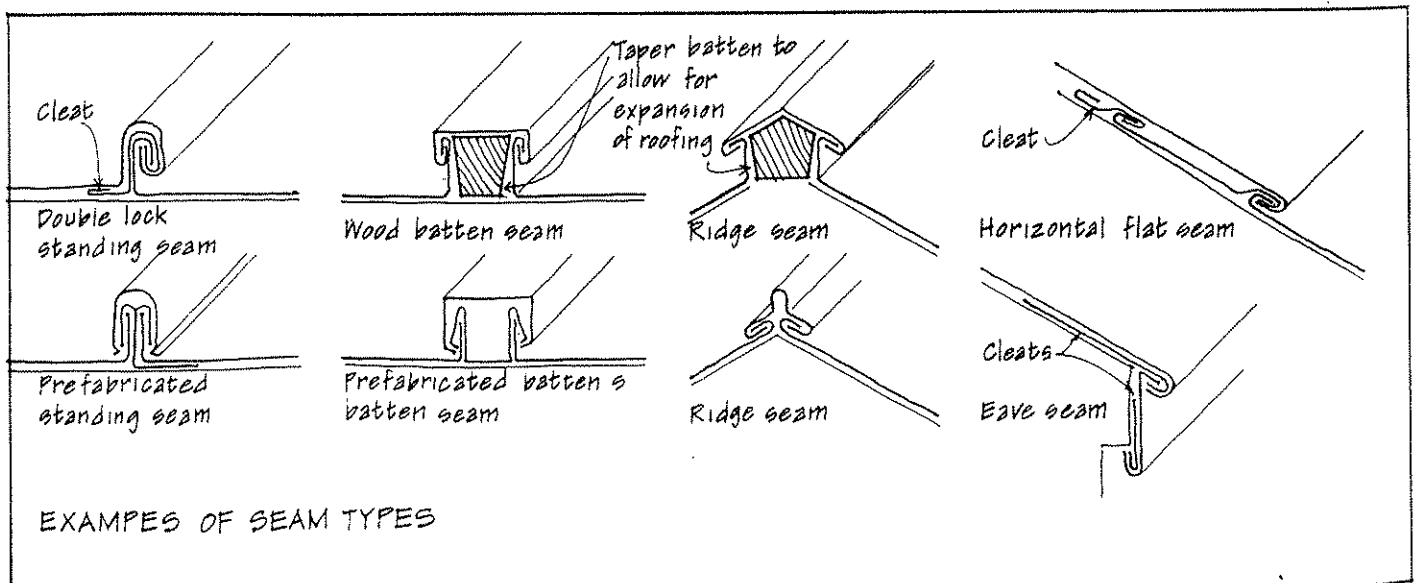


A sheet metal roof is characterized by a strong visual pattern of interlocking seams and articulated ridges and roof edges. The metal sheets may be of copper, zinc alloy, galvanized steel, or terne metal (stainless steel coated with an alloy of tin and lead).

To avoid possible galvanic action in the presence of rain water, flashing, fastenings, and metal accessories should be of the same metal as the roofing material. Other factors to consider in the use of metal roofing are the metal's weathering characteristics and coefficient of expansion.

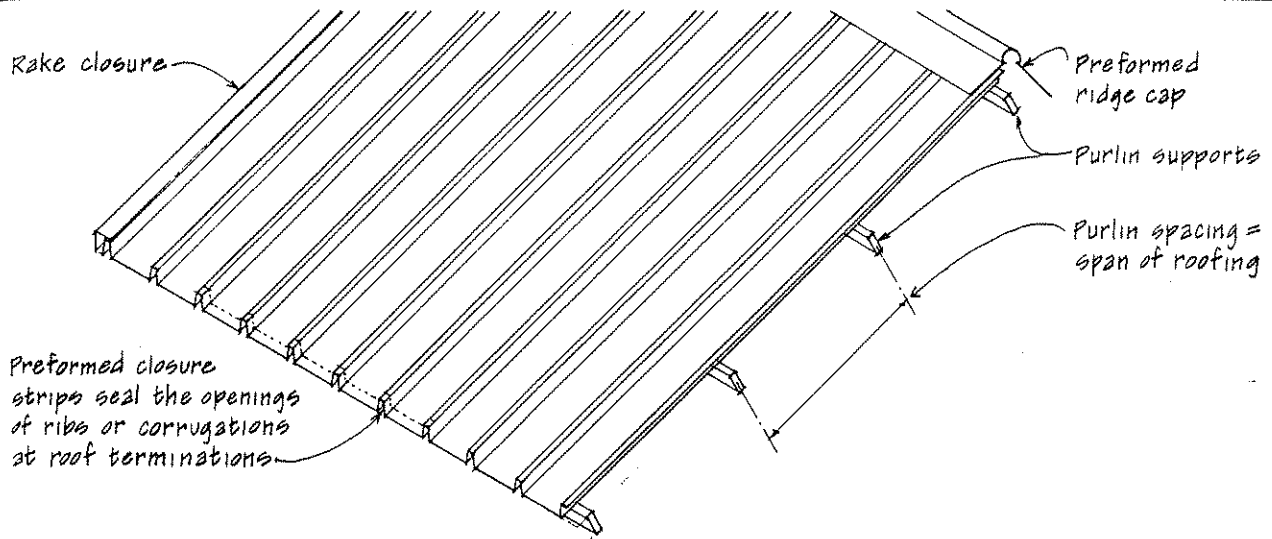


Minimum slope - may be less if locked and soldered seams are used.



CORRUGATED ROOFING

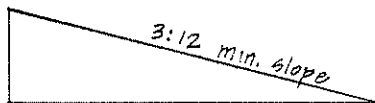
.15



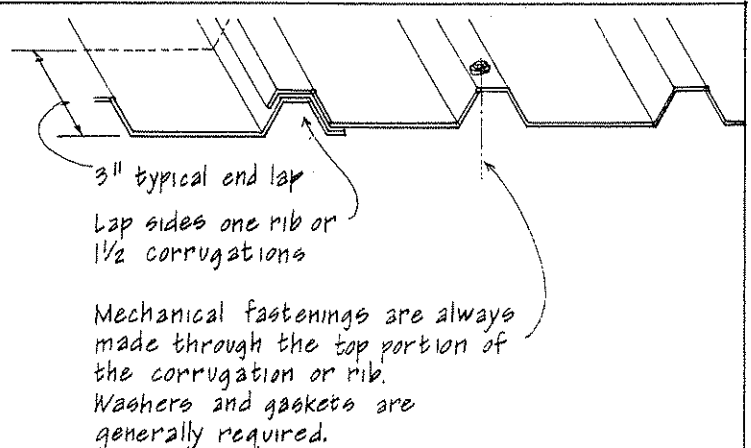
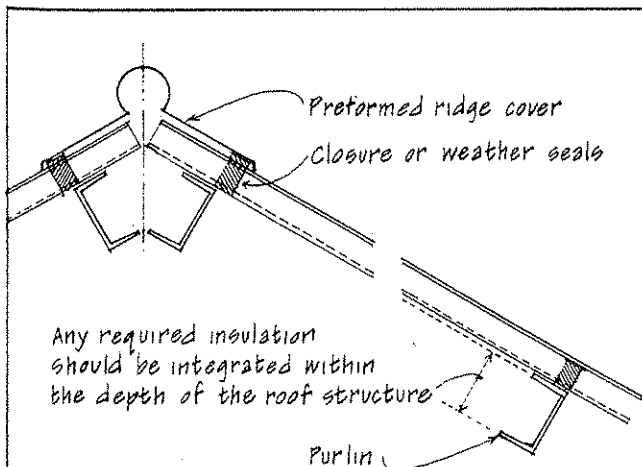
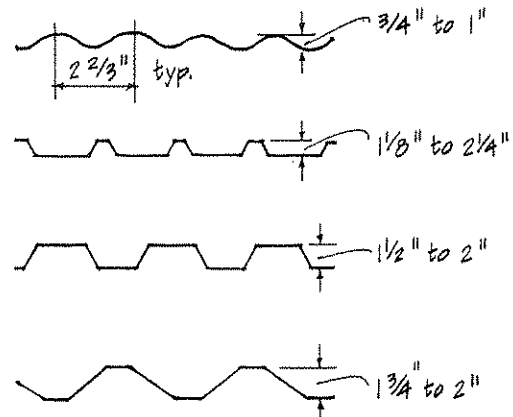
Corrugated or ribbed roofing panels are self-supporting and span between roof beams or purlins running across the slope. The roofing panels may be of:

- Aluminum, natural mill or enameled
- Galvanized steel
- Asbestos cement
- Fiberglass or reinforced plastic
- Corrugated structural glass

Consult manufacturer for material specifications, panel sizes and weights, finishes, allowable spans, and installation details.

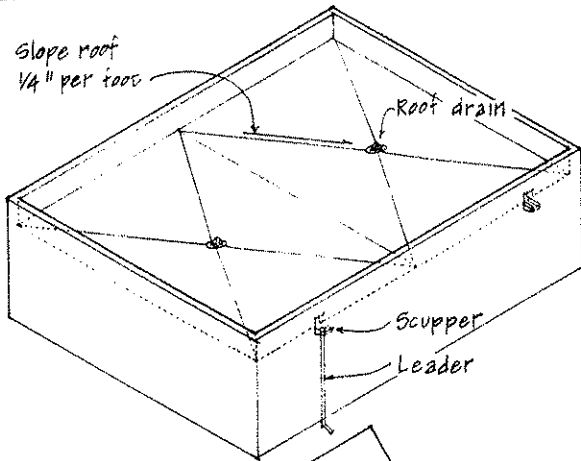


Many corrugation and rib patterns are available.



§.14 ROOF DRAINAGE

Slope roof
1/4" per foot

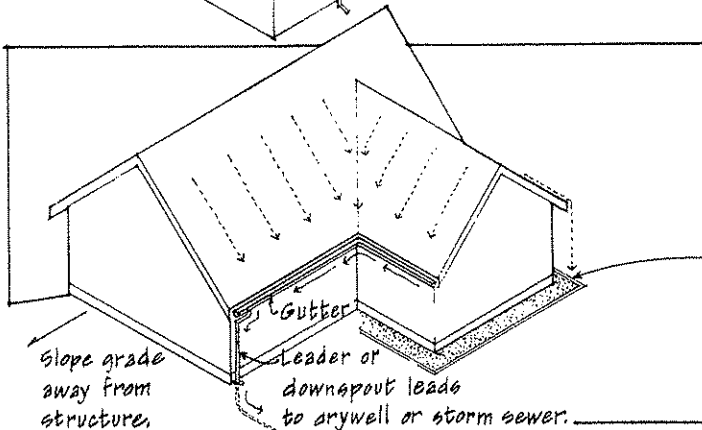


The amount of rain or melting snow a roof and its drain systems must handle is a function of:

- The roof area leading to the drain or gutter
- The frequency and intensity of the rainfall for the building's region.

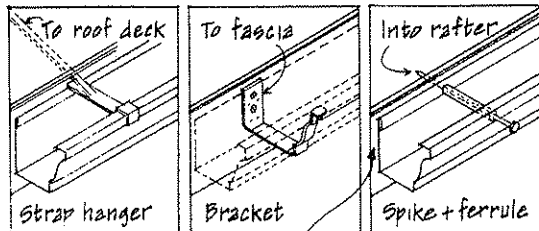
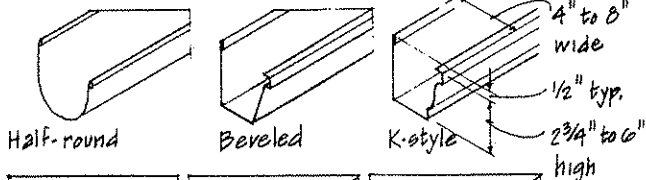
Flat roofs should be pitched to roof drains located at a roof's low points and which connect to the building's storm drain system.

A system of scuppers or overflow drains is also required with the inlet flow 2" above the roof's low points.

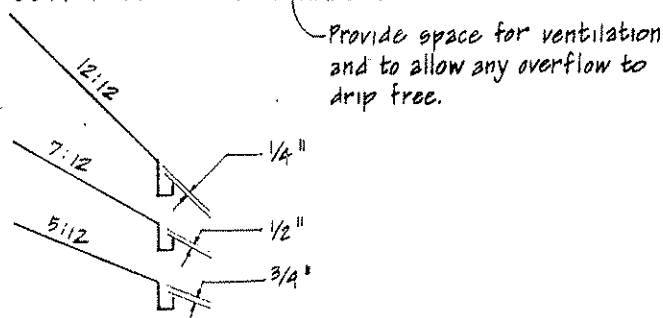


Rain water shed by sloping roofs should be caught by gutters along the eave to prevent ground erosion. Gutters empty into vertical downspouts or leaders which, in turn, discharge into a dry well or storm sewer system.

In dry climates or for small roof areas with adequate overhangs, gutters may be omitted and a bed of gravel or a masonry strip set in the ground under the eave line.

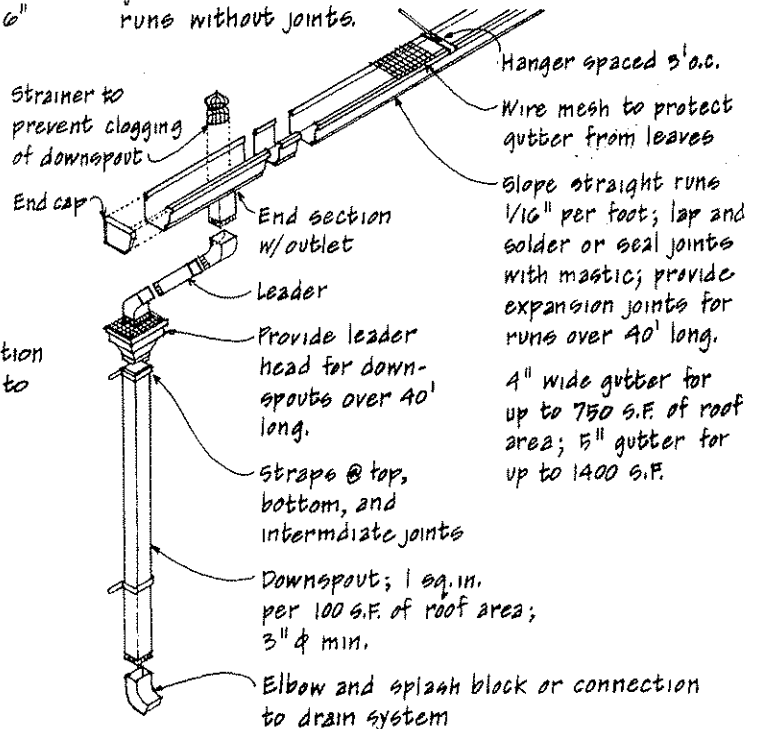


GUTTER SHAPES AND HANGERS



Place gutters below the roof slope line so that snow or ice can slide free.

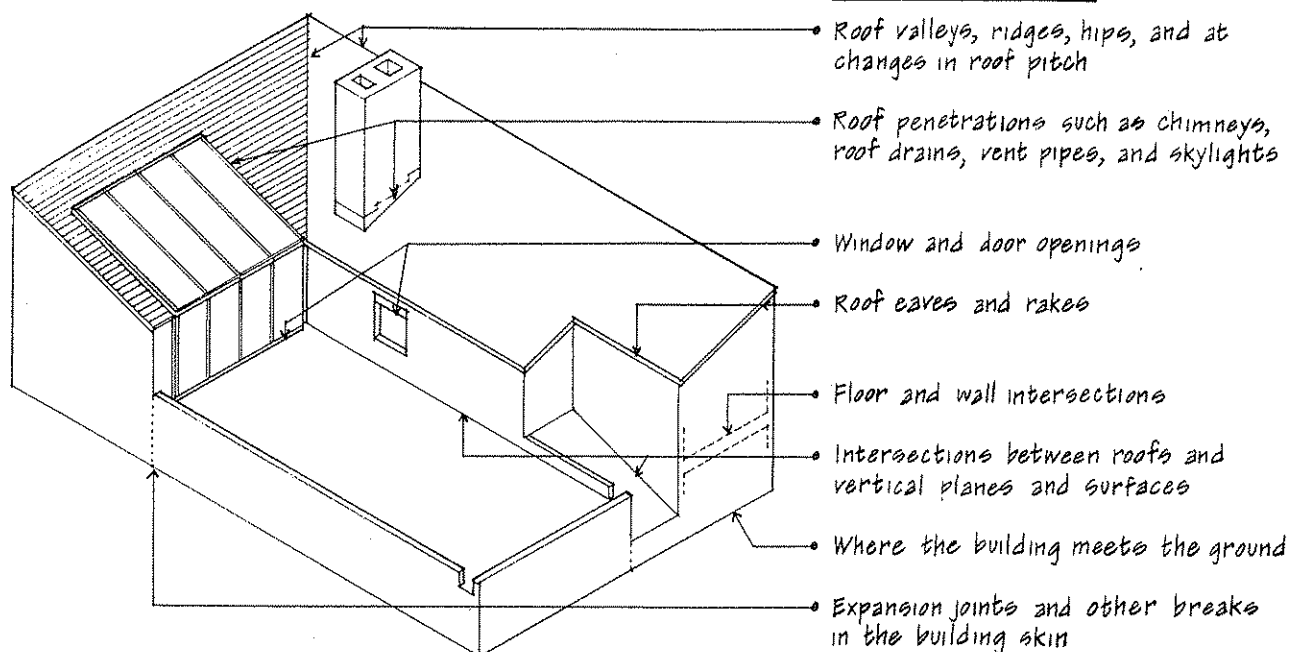
Gutters are typically of vinyl, galvanized steel, or aluminum, although copper, stainless steel, terne, and wood ones are also available. Aluminum gutters can be cold-formed on site in continuous runs without joints.



FLASHING

CD 15

FLASHING LOCATIONS



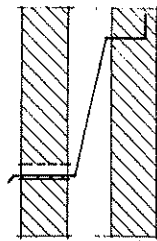
Flashing refers to the thin, impervious materials used to prevent water from entering the joints of a building. Flashing generally operates on the principle that, for water to penetrate a joint, it must work itself upward against the force of gravity, or, in the case of wind driven rain, it would have to follow a tortuous path during which the driving force is dissipated. (See also 7.29 for discussion of pressure-equalization design.)

Flashing may be exposed or concealed. Exposed flashing is usually of sheet metal:

Metal flashing should be provided with expansion joints on long runs to prevent deformation of the flashing. Metal flashing also should not stain or be stained by adjacent materials, or react chemically with them.

aluminum
copper
painted galv. steel
stainless steel
zinc alloy
terne metal
copper-clad lead

Flashing concealed within a building's construction may be of metal or a waterproof membrane such as bituminous fabric or plastic sheet material.

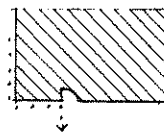


Water must work against gravity at upturned edges.

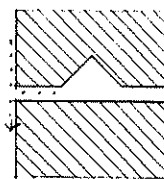
Sloping surfaces use gravity to lead water to the outside.



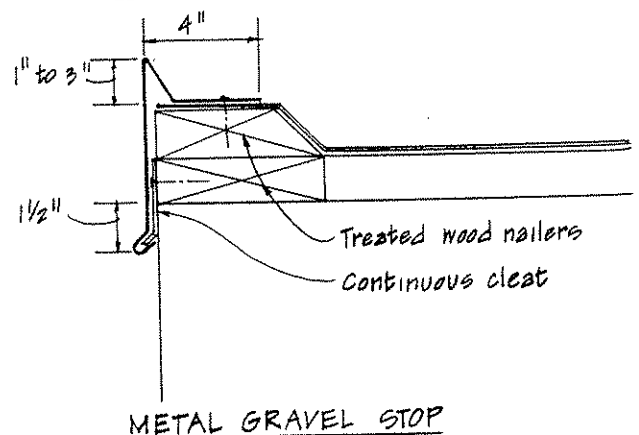
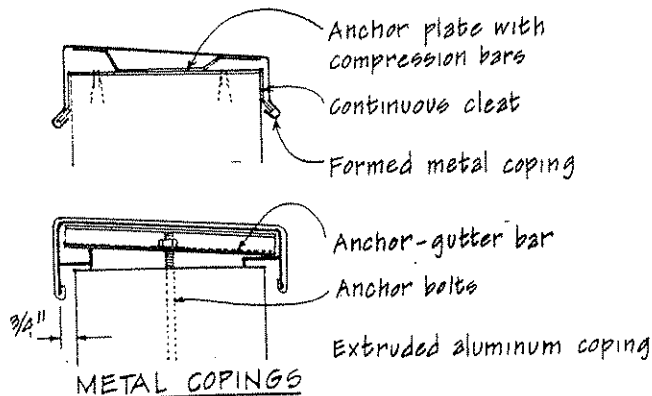
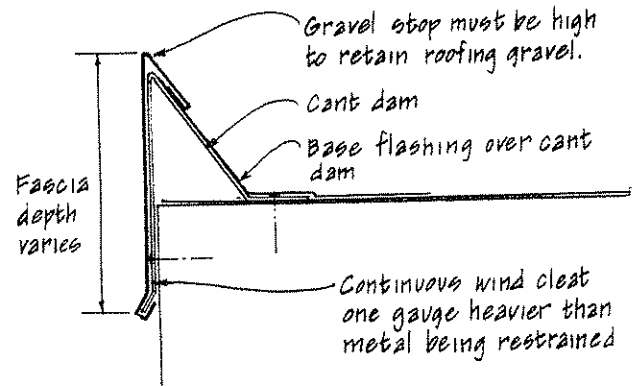
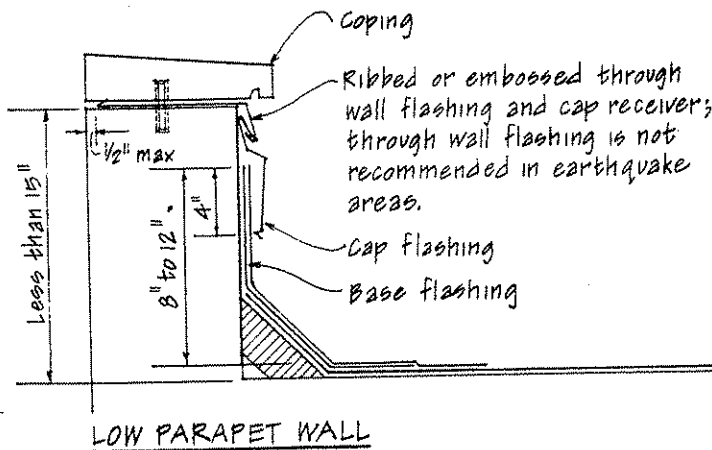
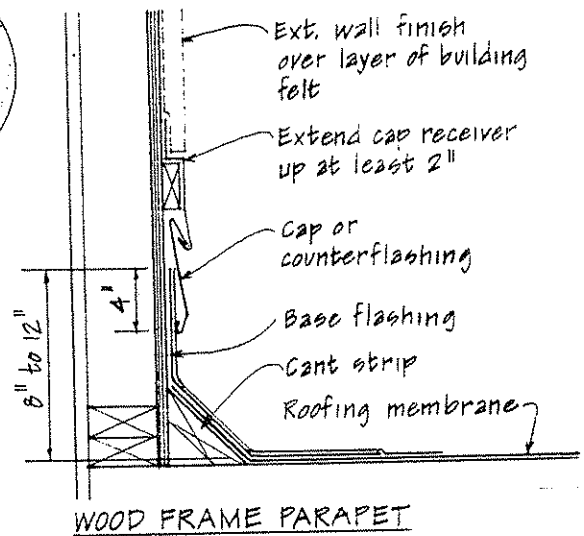
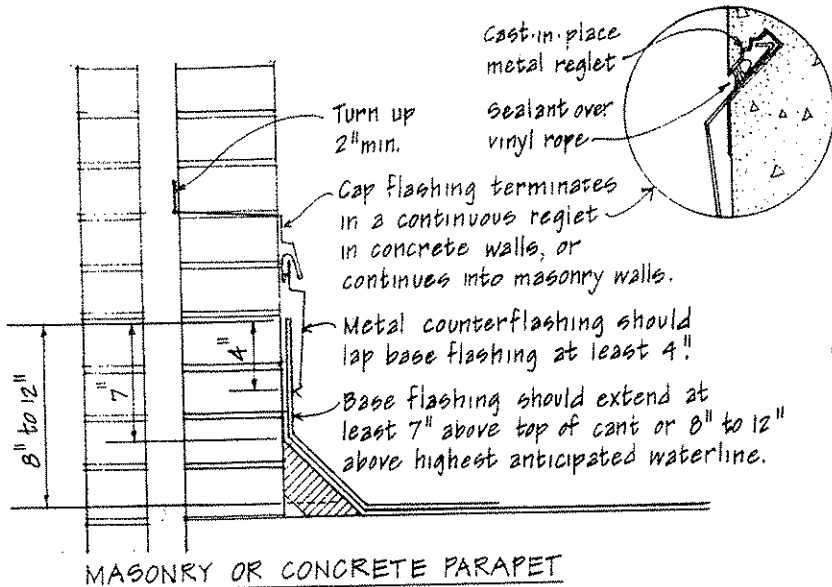
Interlocking seams form a labyrinth which inhibits the passage of water.



While drips and cavities are not flashing, they help stop water from penetrating through surface tension and capillary action.



§.16 ROOF FLASHING

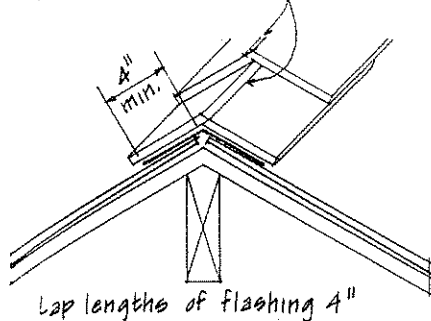


The flashing details on this and the following pages illustrate general conditions and can be adapted for use with various building materials and assemblies.

Consult manufacturer's literature for details of flashing and roofing accessories.

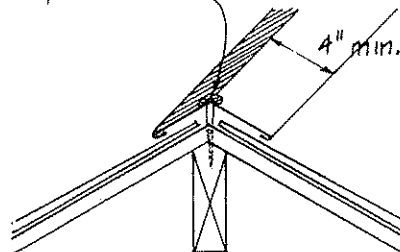
ROOF FLASHING

Lap shingles in
alternate directions



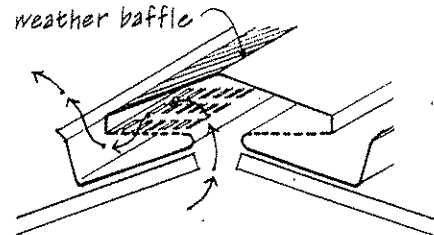
RIDGE FLASHING - CONCEALED

Flashing is attached
with screws and
neoprene washers

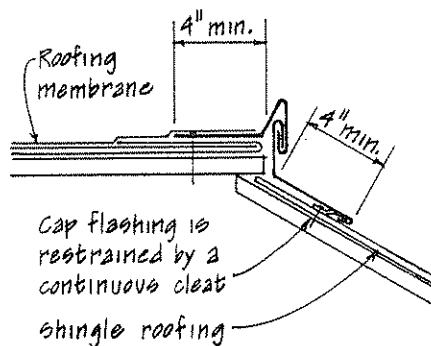


RIDGE FLASHING - EXPOSED

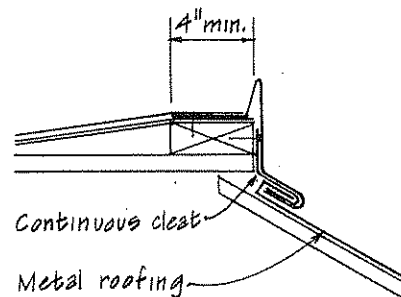
Formed metal ridge
vent with
weather baffle



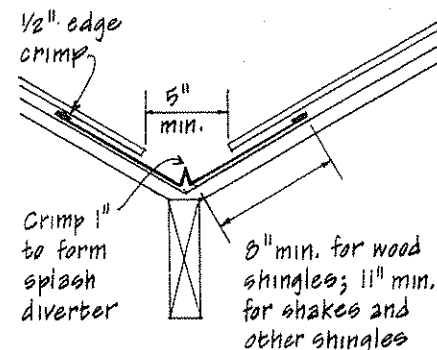
RIDGE VENT



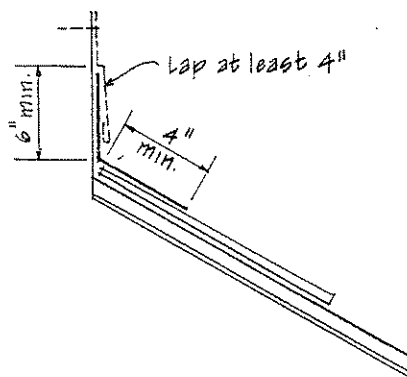
FLAT TO SLOPING ROOF



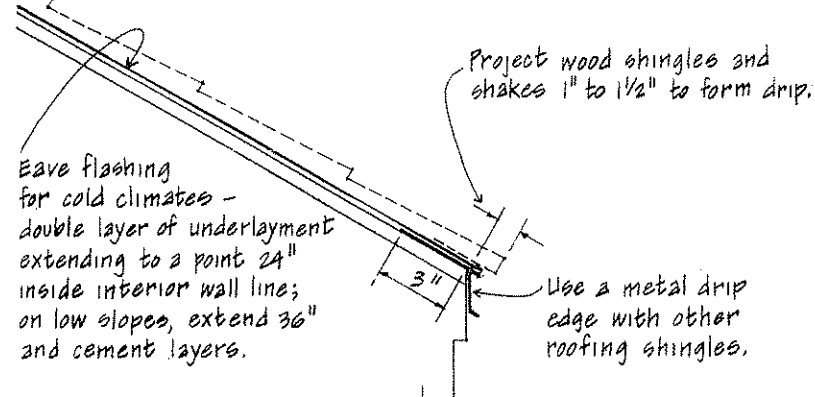
FLAT TO SLOPING ROOF



EXPOSED VALLEY



TOP OF SHED @ WALL

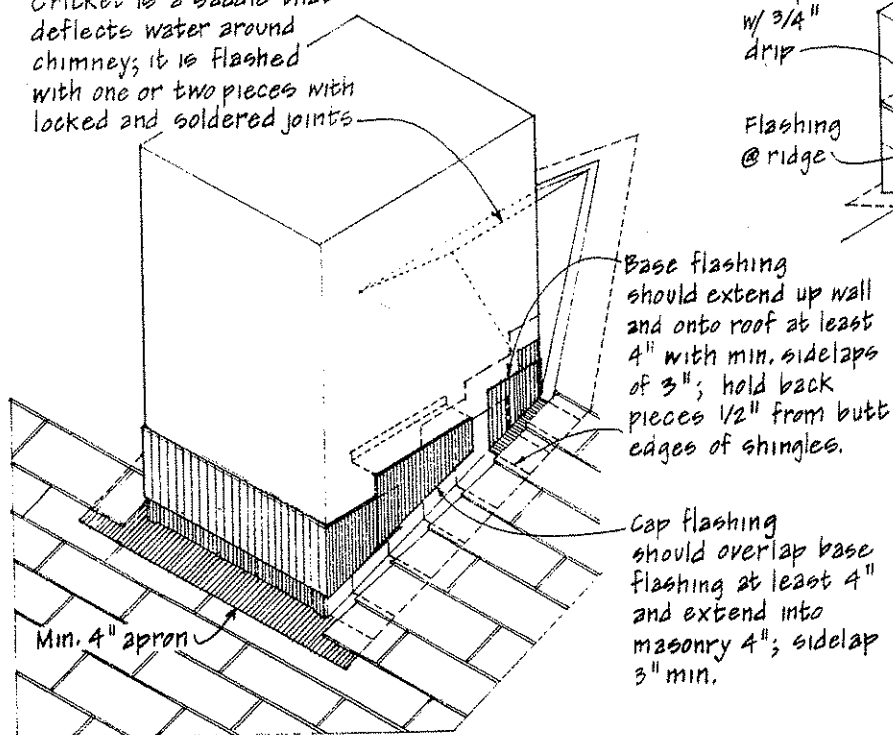


ROOF EAVE

All dimensions are minimum. Weather conditions and roof slope may dictate greater overlaps.

§.18 FLASHING ROOF PENETRATIONS

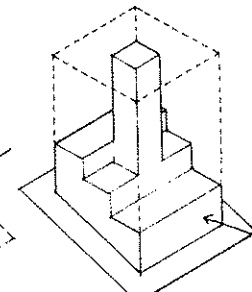
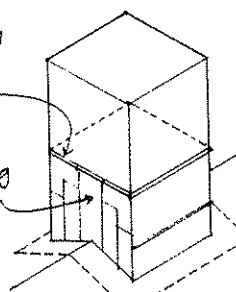
Cricket is a saddle that deflects water around chimneys; it is flashed with one or two pieces with locked and soldered joints.



CHIMNEY FLASHING

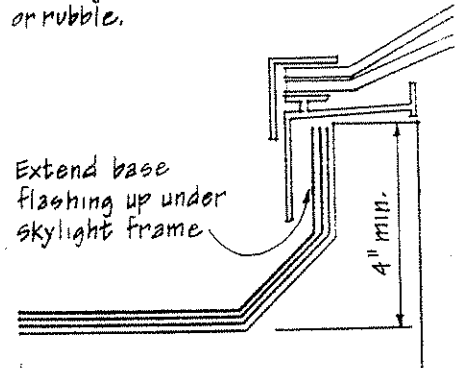
Flat pan w/ 3/4" drip

Flashing @ ridge

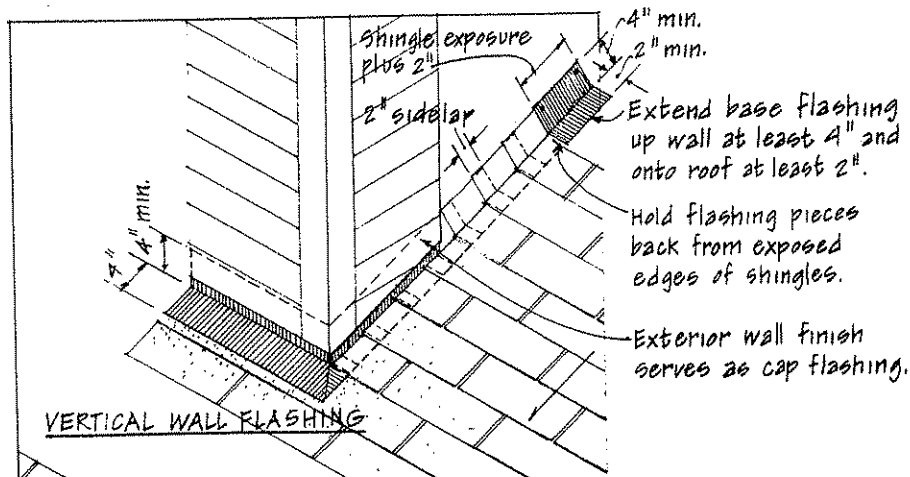


Stepped-pan through wall flashing is used for chimney built of porous masonry materials such as stone or rubble.

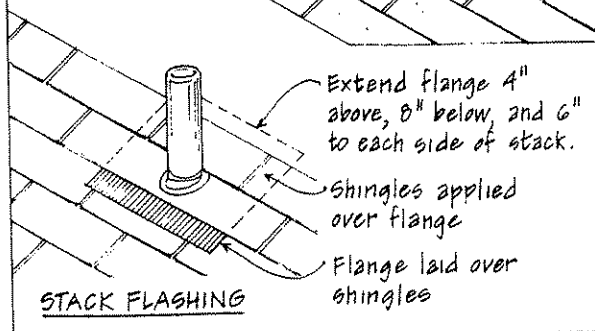
Extend base flashing up under skylight frame



SKYLIGHT



VERTICAL WALL FLASHING



STACK FLASHING

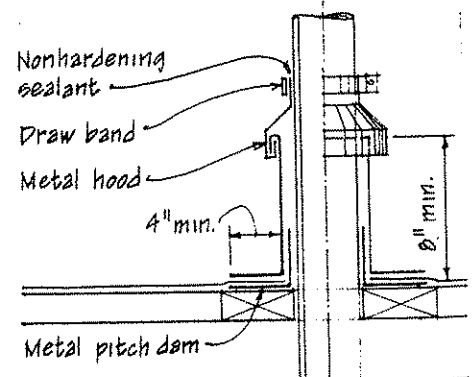
Nonhardening sealant

Draw band

Metal hood

4" min.

Metal pitch dam



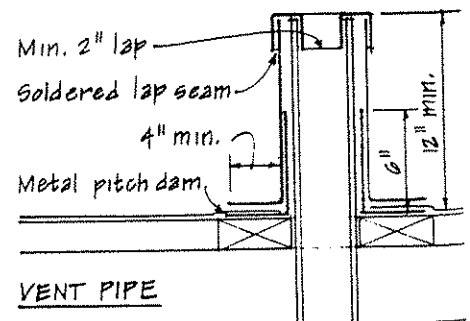
TALL PIPE OR POLE

Min. 2" lap

Soldered lap seam

4" min.

Metal pitch dam



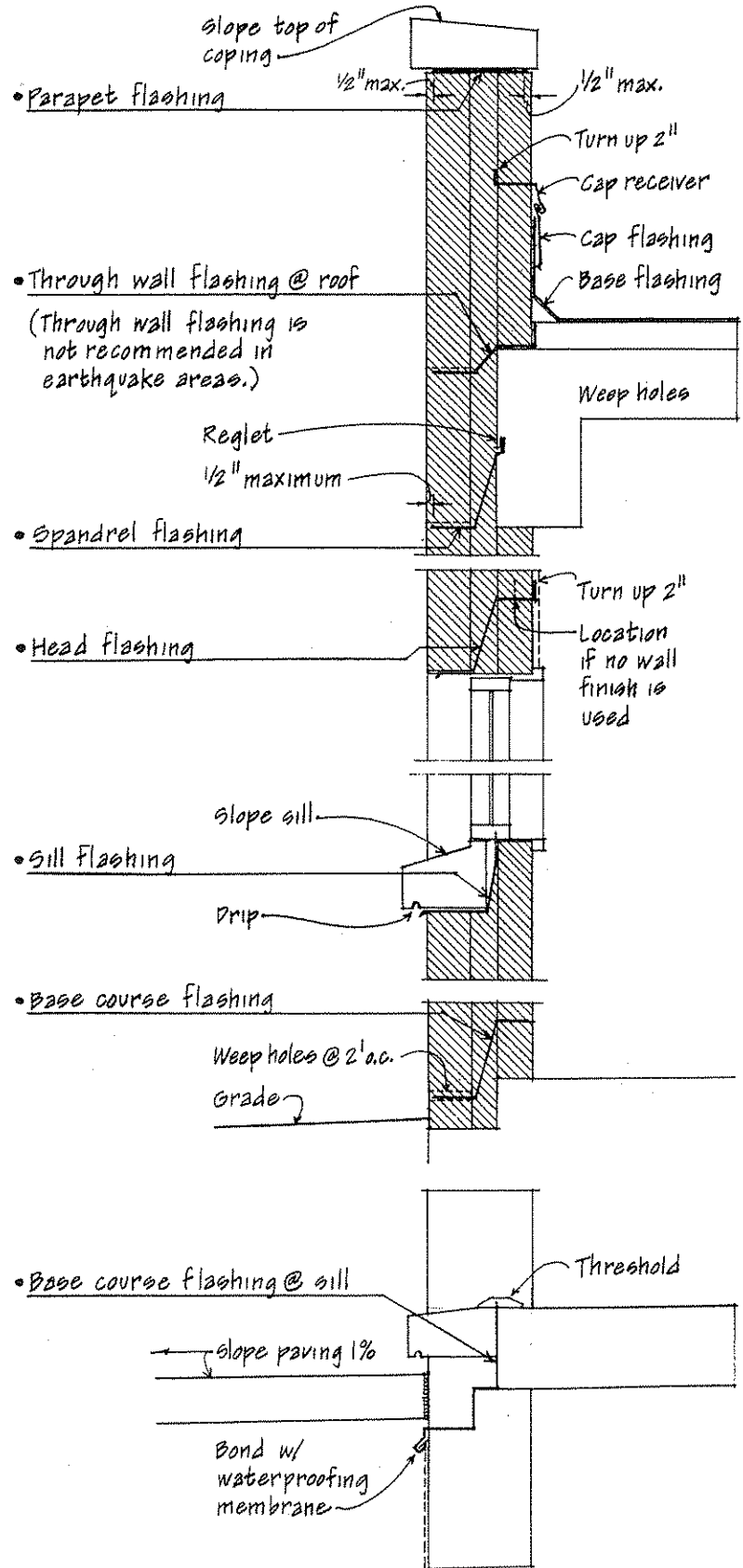
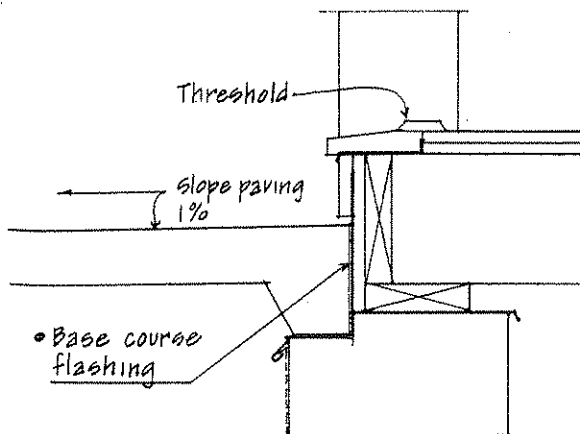
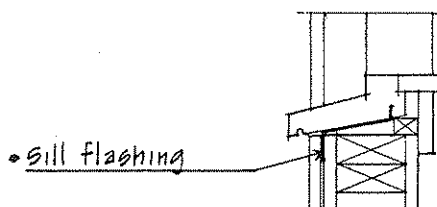
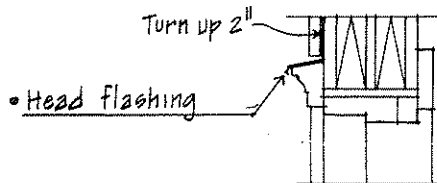
VENT PIPE

WALL FLASHING

Wall flashing is installed to collect any moisture that may penetrate a wall and divert it to the outside through weep holes. The drawings on this page illustrate where wall flashing is usually required.

Masonry walls are especially susceptible to water penetration. Rain penetration can be controlled by properly tooling mortar joints, sealing joints such as those around window and door openings, sloping the horizontal surfaces of sills and copings, and coating the wall with a silicone-based sealer. Cavity walls are also effective in resisting water penetration.

Flashing in masonry walls require weep holes which are formed in the head joints directly above the flashing at 2' o.c.



A foundation system should be waterproofed to prevent ground water, under hydrostatic pressure or through capillary action, from penetrating the substructure. Waterproofing requires a continuous water-resistant membrane that is capable of sealing off those parts of a foundation which come into contact with the earth.

If subsoil conditions do not cause water to build up under hydrostatic pressure, the foundation wall can simply be parged to control moisture penetration due to capillarity. Parging consists of two 1/4" coats of Type M mortar from the footing to 6" above grade. A coal tar or asphaltic coating can be applied over the parging for increased moisture resistance.

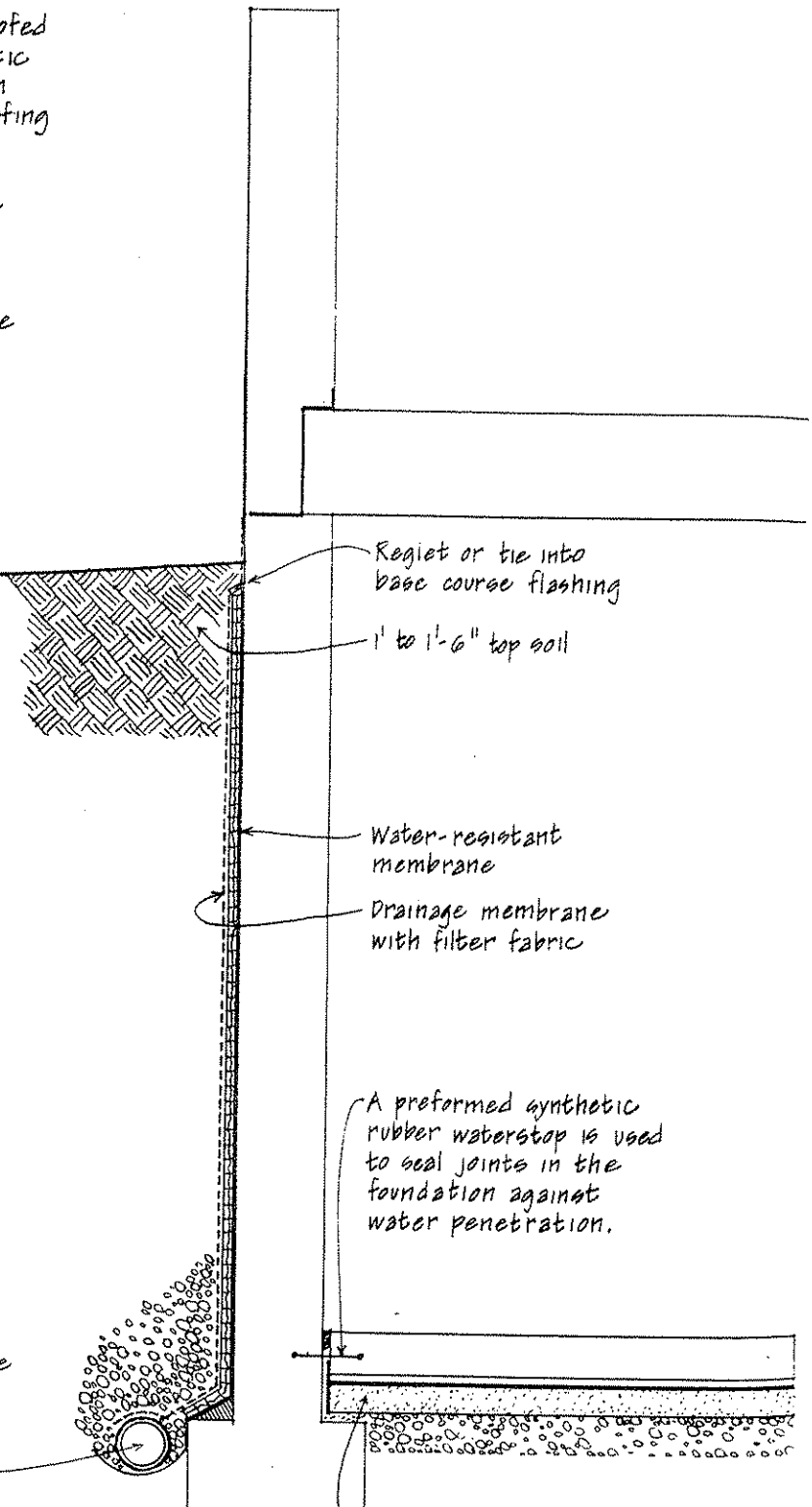
Water-resistant membranes for basement walls and slabs may also consist of:

- Butyl rubber or polyvinyl chloride (PVC) sheets with laps sealed with adhesive or cement
- Cementitious plaster coatings
- Bentonite clay which swells when wetted to become impervious; sprayed on or applied in sheet form.

Water-resistant membranes require a rigid, stable, and level substrate and protection while backfilling.

Gravel or a drainage membrane with filter fabric is used to allow water to flow down to the footing drains.

Equally as important as waterproofing is a drainage system that can help to relieve any buildup of hydrostatic pressure against the basement wall. It usually consists of perforated pipe or tile, 4" in diameter. These footing drains should be sloped to lead water to a storm sewer system, a sump, or to daylight when on a slope.



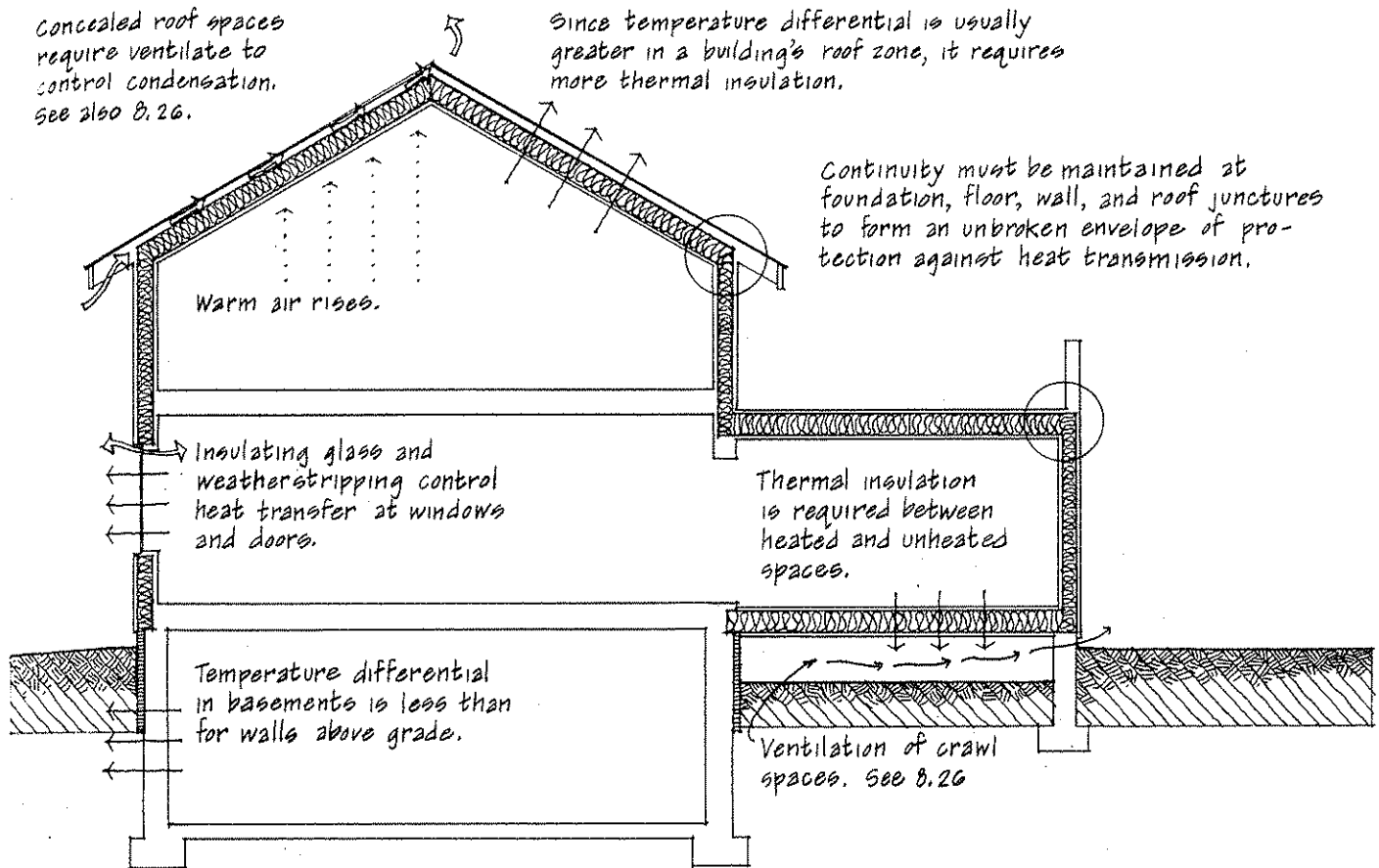
When a membrane is required under the floor slab, it is laid over a subslab.

THERMAL INSULATION

Concealed roof spaces require ventilate to control condensation. See also 8.26.

Since temperature differential is usually greater in a building's roof zone, it requires more thermal insulation.

Continuity must be maintained at foundation, floor, wall, and roof junctures to form an unbroken envelope of protection against heat transmission.



RECOMMENDED MINIMUM THERMAL RESISTANCES (R)
OF BUILDING INSULATION *

Zone	Ceiling or roof	Exterior wall	Floor over unheated space
Minimum recommended	19	11	11
Southern zone	26	13	11
Temperate zone	30	19	13
Northern zone	38	19	22

* These R-values are only general recommendations. Check the local or state energy code for specific recommendations.

The primary purpose of a building's thermal insulation is to control heat transfer through its exterior assemblies and thereby prevent excessive heat loss in cold seasons and heat gain in hot weather. This control can effectively reduce the amount of energy required by the building's heating and cooling equipment to maintain conditions for human comfort.

- For further discussion of the factors that affect human comfort, see 11.2-11.3.
- For building siting factors that also affect a building's potential heat loss or gain, see Chapter 1.

Material		1/k	1/c	Material		1/k	1/c	
WOOD	Hardwoods	0.91	0.82	METAL	Aluminum0007		
	Softwoods	1.25			Brass0010		
	Plywood	1.25			Copper0004		
	Particleboard, 5/8"				Lead0041		
	Wood fiberboard	2.00			Steel0032		
MASONRY UNITS	Common brick	0.20	1.11 2.00	GLASS	Single, clear, 1/4"		0.88	
	Face brick	0.11			Double, clear, 3/16" space ..		1.61	
	Concrete block, 8", Sand & gravel aggregate ..				1/4" space ..		1.72	
	Lightweight aggregate ..				1/2" space ..		2.04	
	Granite and marble	0.05			Double, blue/clear		2.25	
	Sandstone	0.08			gray/clear		2.40	
CONCRETE & MASONRY MATERIALS	Concrete, Sand & gravel aggregate ..	0.08			green/clear		2.50	
	Lightweight aggregate ..	0.60			Double, clear, with low emittance coating...		3.23	
	Cement mortar	0.20			Triple, clear		2.56	
	Stucco	0.20			Glass block, 4"		1.79	
ROOFING	Built-up roofing		0.33	AIR SPACE	3/4", nonreflective		1.01	
	Fiberglass shingles		0.44		3/4", reflective		3.48	
	Slate roofing		0.05					
	Wood shingles		0.94					
SIDING	Aluminum siding		0.61					
	Wood shingles		0.87					
	Wood bevel siding		0.81					
	Vinyl siding		1.00					
BUILDING PAPER	Vapor-permeable felt		0.06					
	Polyethylene film		-0-					
DOORS	Steel, polystyrene core ..		2.13					
	Steel, urethane core ...		5.56					
	Wood hollow core, 1 3/4" ...		2.04					
	Wood solid core, 1 3/4" ...		3.13					
PLASTER & GYPSUM	Cement plaster, Sand aggregate	0.20	0.45					
	Gypsum plaster, lightweight aggregate...	0.67						
	Gypsum board, 1/2"							
FLOORING	Carpet & pad		1.50					
	Hardwood, 25/32"		0.71					
	Terrazzo		0.08					
	Vinyl tile		0.05					

1/k = (R) per inch of thickness
1/c = (R) for the thickness indicated

(R) is a measure of a material's resistance to heat flow. It is expressed as the temperature difference required to cause heat to flow through a unit area of material at the rate of one heat unit per hour.
(F°/Btu/hr. ft²)

(R_T) is the total thermal resistance for a construction assembly, and is simply the sum of the individual R-values of assembly's component materials.

(U) is the overall heat transfer coefficient, and expresses the rate of heat transfer through a unit area of a building component caused by a difference of one degree between the air temperatures on the two sides of the component. The U-value for a component or assembly is the reciprocal of its R-value
(U = 1/R_T)

(Q) is the rate of heat flow through a construction assembly and is equal to:
U x A x (t_i - t_o), where

1/k = (R) per inch of thickness

1/c = (R) for the thickness indicated

(R) is a measure of a material's resistance to heat flow. It is expressed as the temperature difference required to cause heat to flow through a unit area of material at the rate of one heat unit per hour.
($F^{\circ}/\text{Btu/hr} \cdot \text{ft}^2$)

(R_T) is the total thermal resistance for a construction assembly, and is simply the sum of the individual R-values of assembly's component materials.

(U) is the overall heat transfer coefficient, and expresses the rate of heat transfer through a unit area of a building component caused by a difference of one degree between the air temperatures on the two sides of the component. The U-value for a component or assembly is the reciprocal of its R-value.
($U = 1/R_T$)

(Q) is the rate of heat flow through a construction assembly and is equal to:

$$U \times A \times (t_i - t_o), \text{ where}$$

U = overall coefficient of assembly

A = exposed area of assembly

($t_i - t_o$) is the difference between the inside and outside air temperatures.

The table above can be used to estimate the thermal resistance of a construction assembly. For specific R-values of materials and building components such as windows, consult the manufacturer.

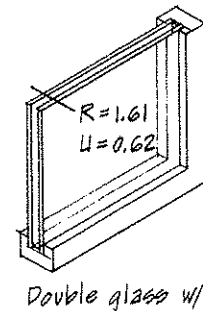
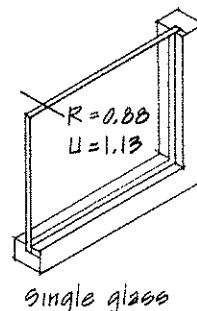
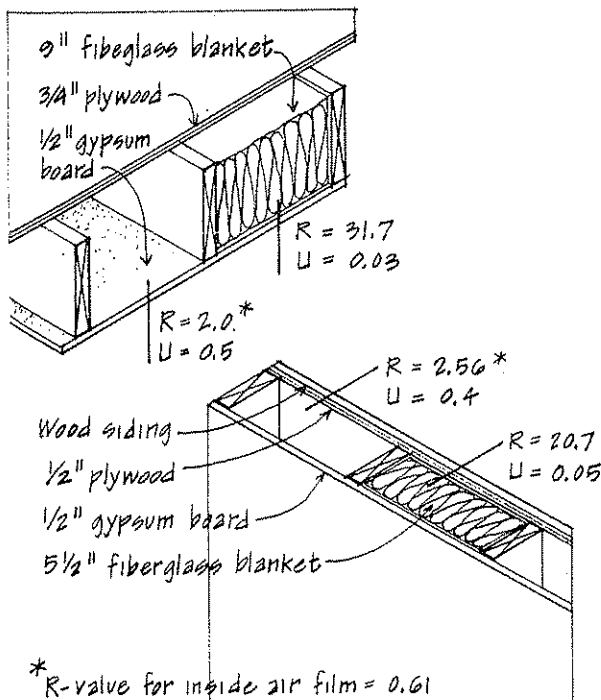
INSULATING MATERIALS

Form	Material	R-value per inch of thickness	
BATT OR BLANKET	Fiberglass	3.3	Installed between studs, joists, rafters, or furring; considered incombustible except for paper facing.
	Rock wool	3.3	
RIGID BOARDS	Cellular glass	2.5	Boards may be applied over a roof deck, over wall framing as sheathing, in cavity walls, or beneath an interior finish material; the plastics are combustible and give off toxic fumes when burned; extruded polystyrene can be used in contact with the earth but any exposed sur- faces should be protected.
	Polystyrene, molded	3.6	
	Polystyrene, extruded ...	5.0	
	Polyurethane, expanded ..	6.2	
	Polyisocyanurate	7.2	
	Perlite, expanded	2.6	
FOAMED IN PLACE	Polyurethane	6.2	Used to insulate irregularly shaped spaces.
LOOSE FILL	Cellulose	3.7	Used to insulate attic floors and wall cavities; cellulose can be combined with adhesives for sprayed application; cellulose should be treated and UL listed for fire resistance.
	Perlite	2.7	
	Vermiculite	2.1	
CAST	Insulating concrete	1.1	Used primarily as an insulating layer under membrane roofing; insulating value depends on its density.

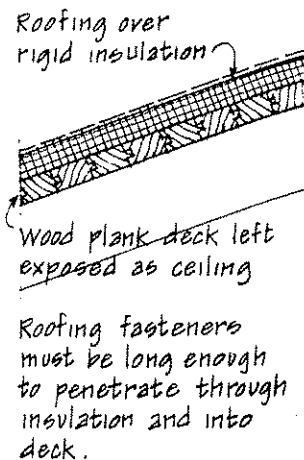
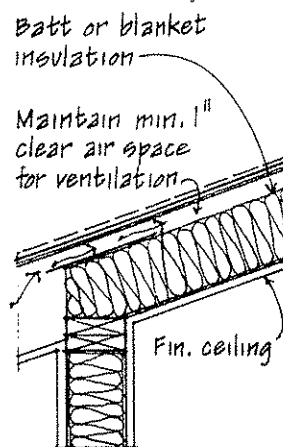
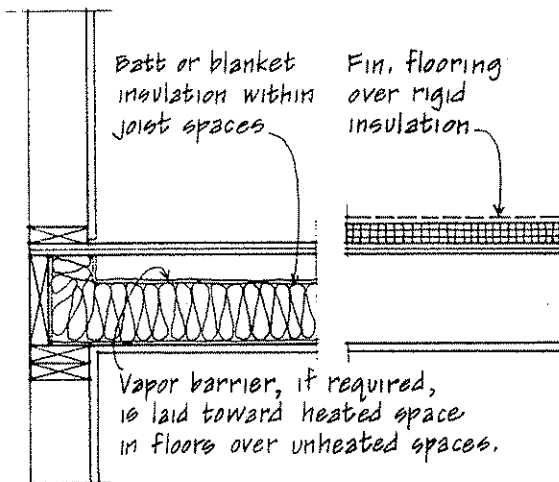
Almost all building materials offer some resistance to heat flow. To achieve the desired R_T value, however, wall, floor and roof assemblies usually require the addition of an insulating material. The table above outlines the basic forms and materials used to insulate a building's component assemblies.

The steady state method for calculating heat loss or gain (see previous page) takes into account primarily the thermal resistance (R_T) of the construction assembly and the air temperature differential. Other factors that affect heat loss or gain are:

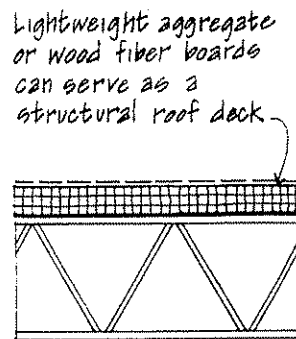
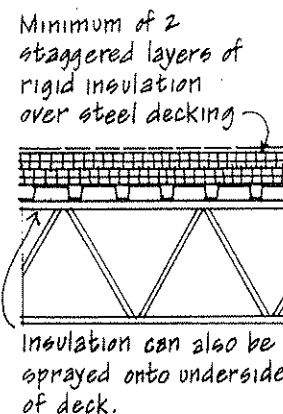
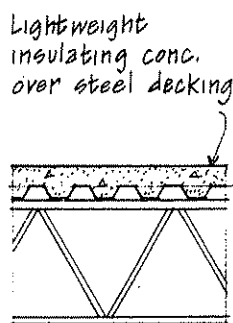
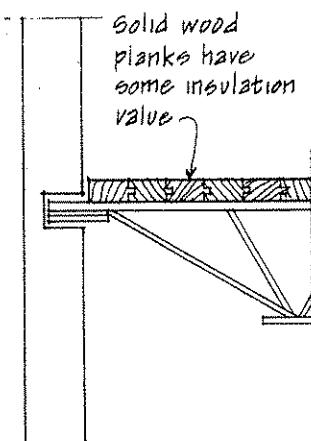
- The surface color and reflectivity of the materials used
- The mass of the assembly, which affects the time lag or delay before any stored heat is released by the structure; time lag becomes a significant factor with thick, dense materials.
- The orientation of the building's exterior surfaces, which affects solar heat gain as well as exposure to wind and the attendant potential for air infiltration.
- Latent heat sources and heat gain from a building's occupants, lighting, and equipment.
- Proper installation of thermal insulation and vapor barriers.



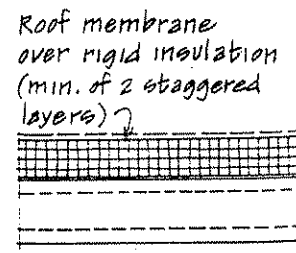
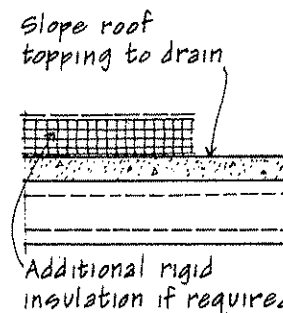
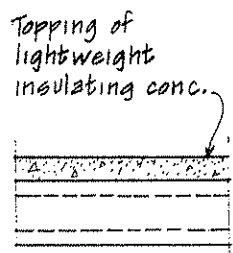
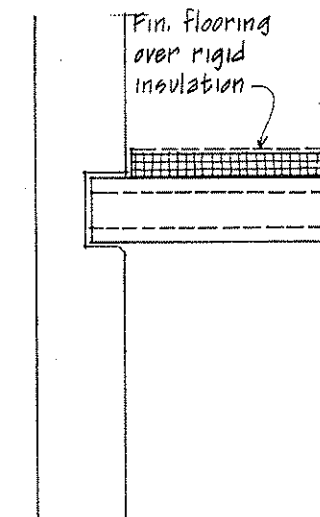
WOOD



STEEL



CONCRETE

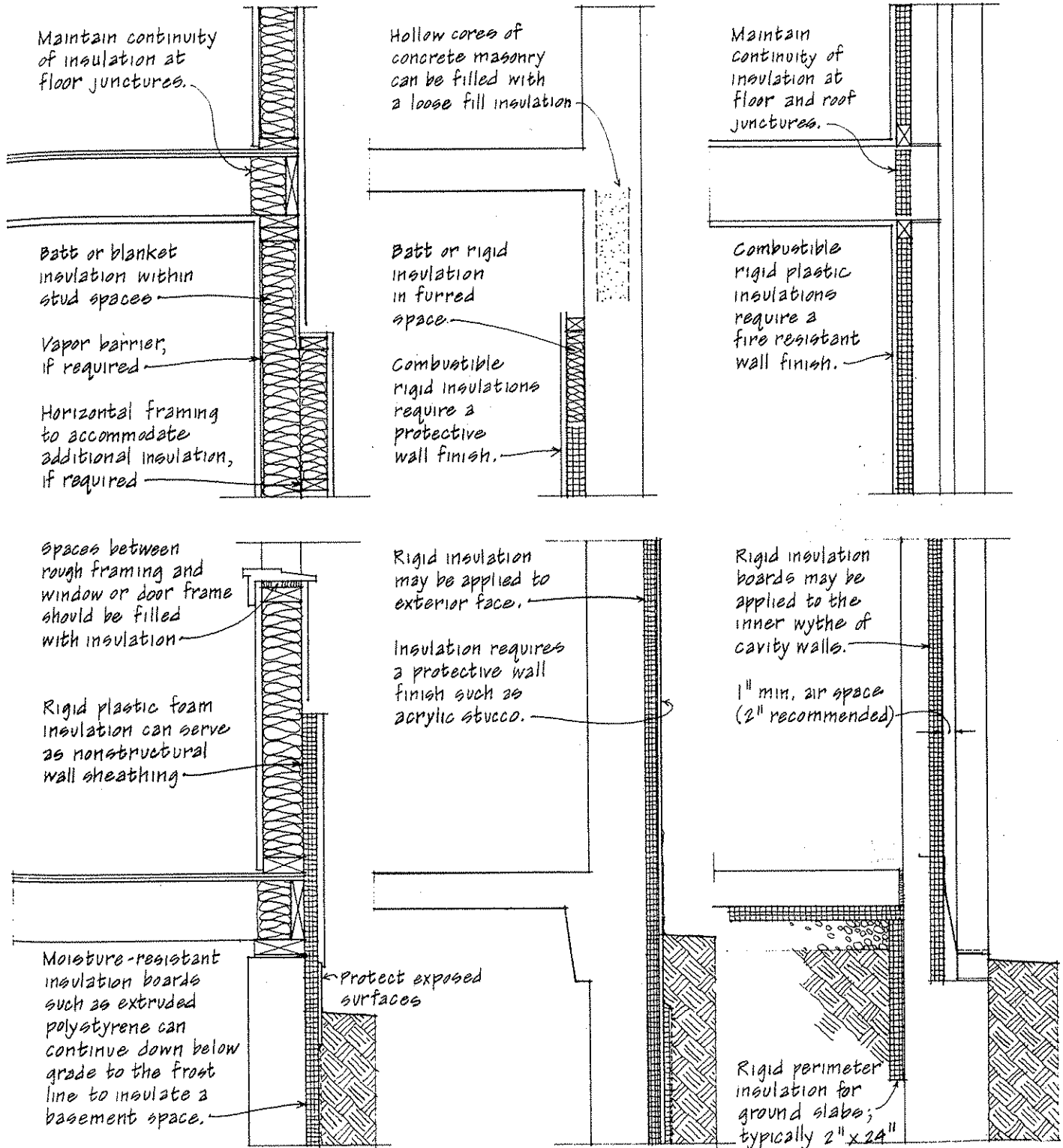


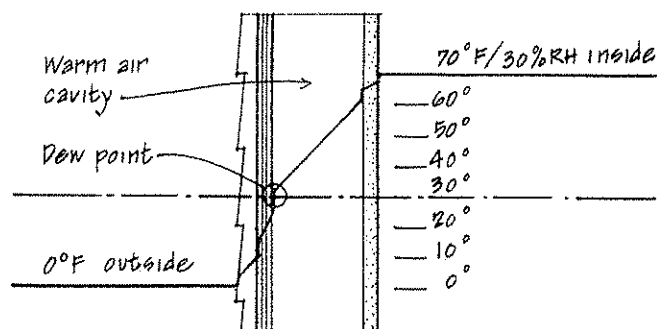
FLOOR CONDITIONS

ROOF CONDITIONS

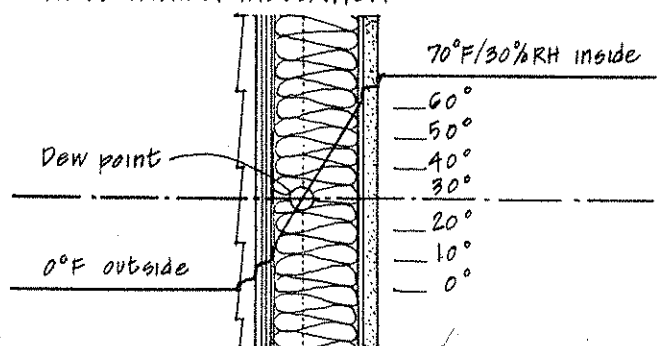
INSULATING WALLS

§.25

FRAME WALLSCONCRETE OR
SOLID MASONRY WALLSMASONRY CAVITY WALLS



WALL WITHOUT INSULATION



WALL WITH INSULATION

requires a vapor barrier to prevent water vapor from condensing within the layer of insulation. A vapor barrier becomes more important as the level of thermal insulation increases.

Moisture is normally present in the air as water vapor. Evaporation from a building's occupants and equipment can raise the air's humidity. This moisture vapor will transform itself into a liquid state (condense) when the air in which it exists becomes completely saturated with all the vapor it can hold and reaches its dew point temperature. Warm air is capable of holding more moisture vapor and has a higher dew point than cooler air.

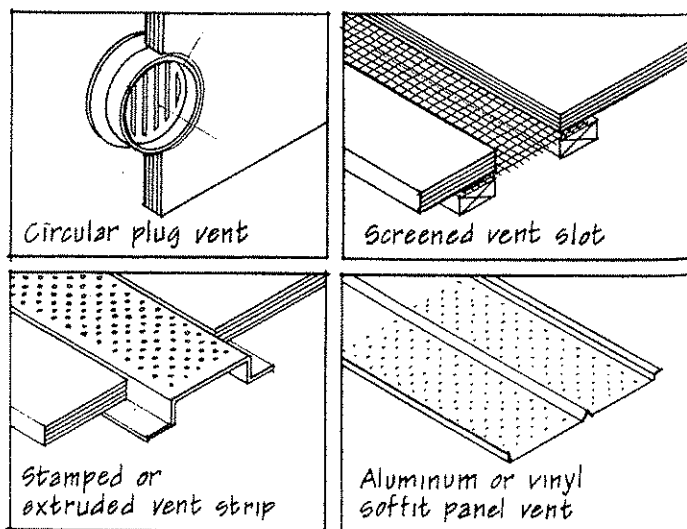
Since it is a gas, moisture vapor always moves from high to lower pressure areas. This normally means it tends to diffuse from the higher humidity levels of a building's interior toward the lower humidity levels outside. This flow is reversed when hot, humid conditions exist outdoors and a building's interior spaces are cool. Most building materials offer little resistance to this passage of moisture vapor. If the moisture vapor comes into contact with a cool surface whose temperature coincides with the air's dew point, it will condense.

Condensation can lessen the effectiveness of thermal insulation, be absorbed by a building's materials, and deteriorate finishes. Moisture vapor, therefore, must be:

- ① prevented by vapor barriers from penetrating the enclosed spaces of exterior construction, and/or
- ② allowed to escape, by means of ventilation, before it can condense into a liquid.

PERMEABILITY OF SOME BUILDING MATERIALS

Material	Permeance (Perm)
Brick, 4"	0.8
Concrete, 1"	3.2
Concrete block, 8"	2.4
Gypsum board, 3/8"	50.0
Plaster, 3/4"	15.0
Plywood, 1/4", exterior glue	0.7
Built-up roofing	0.0
Aluminum foil, 1 mil	0.0
Polyethylene, 4 mil	0.08
Polyethylene, 6 mil	0.06
Duplex sheet, asphalt + foil	0.002
Asphalt saturated + coated paper	0.2
Kraft paper, foil-faced	0.5
Blanket insulation, faced	0.4
Cellular glass	0.0
Polystyrene, molded	2.0
Polystyrene, extruded	1.2
Paint, 2 coats, exterior	0.9



TYPES OF SOFFIT OR EAVE VENTS

VAPOR BARRIERS AND VENTILATION

Ridge ventilation may be provided by a continuous ridge vent, or louvers in the gable end walls.

• ROOF AND ATTIC VENTILATION

is provided by eave vents and, on sloping roofs, by vents close to the ridge. The total net free ventilating area should be at least $1/300$ th of the area of the space being ventilated, with 50% of the required area being at or along the ridge. Openings should be protected against the entrance of rain, snow, and insects.

• VAPOR BARRIERS

are normally placed on the warm (in winter) side of insulated construction.

In warm, humid climates, the vapor barrier may have to be placed on the outer face of the construction.

Some rigid insulation boards have inherent vapor resistance, while other insulating materials have a vapor retarding facing. A vapor barrier is most effective, however, when it is applied as a separate layer with no breaks and with all seams lapped and sealed.

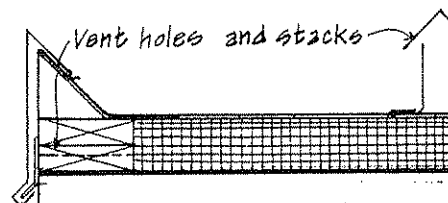
Over unheated spaces, the vapor barrier is placed on the warm side of the insulated floor.

• CRAWL SPACES require a vapor barrier to control ground moisture. Unheated crawl spaces also require ventilation. The openings

should be located on opposite sides of the crawl space and near corners to encourage cross ventilation.

Surface condensation on windows can be controlled by raising the surface temperature with a warm air supply or by using double or triple glazing.

Openings should have a net area of at least $1\frac{1}{2}$ S.F. for each 25 lineal feet of wall.



A vapor barrier for flat roof assemblies is recommended only when the average outdoor January temperature is below 40°F and interior relative humidity is 45% or greater.

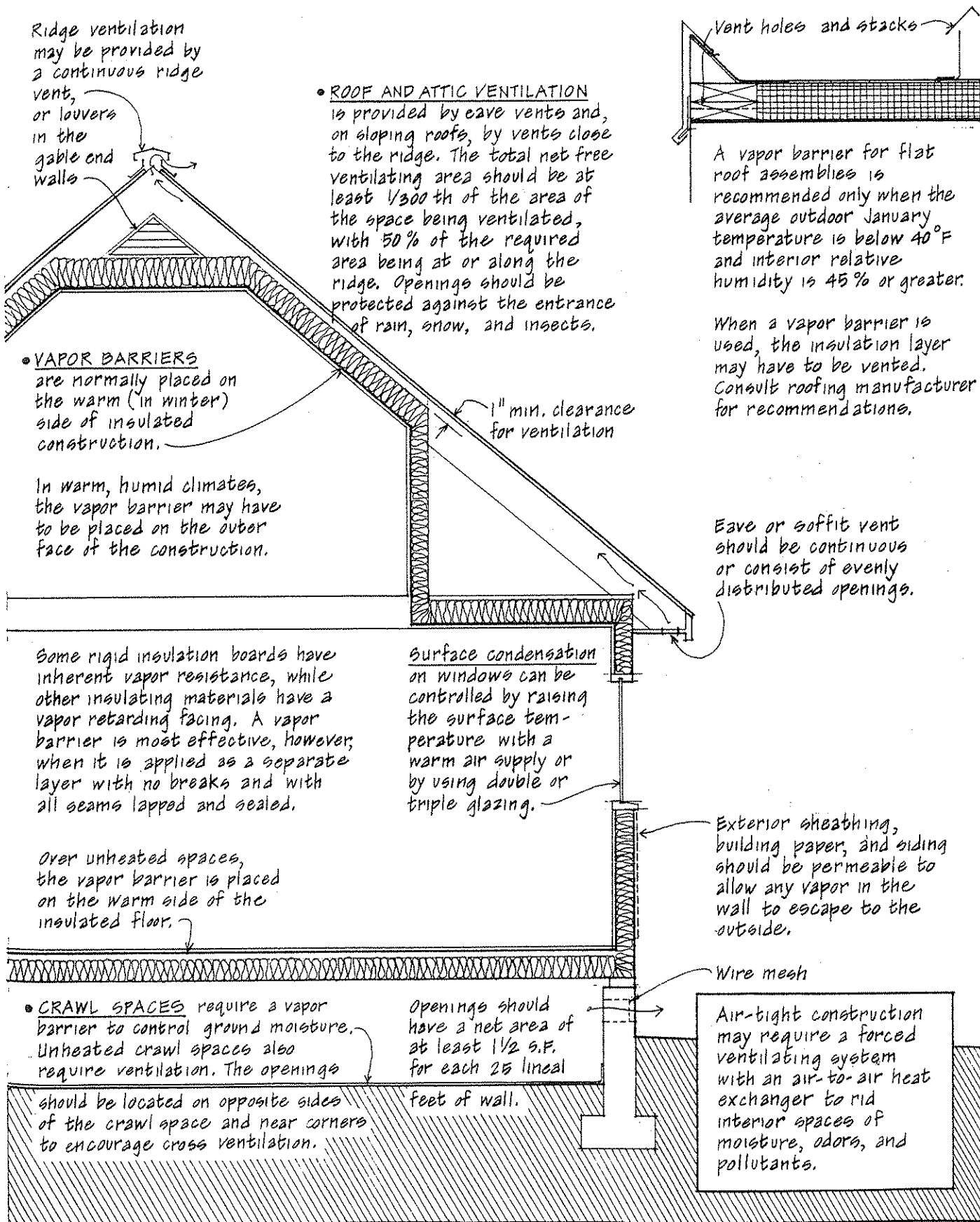
When a vapor barrier is used, the insulation layer may have to be vented. Consult roofing manufacturer for recommendations.

Eave or soffit vent should be continuous or consist of evenly distributed openings.

Exterior sheathing, building paper, and siding should be permeable to allow any vapor in the wall to escape to the outside.

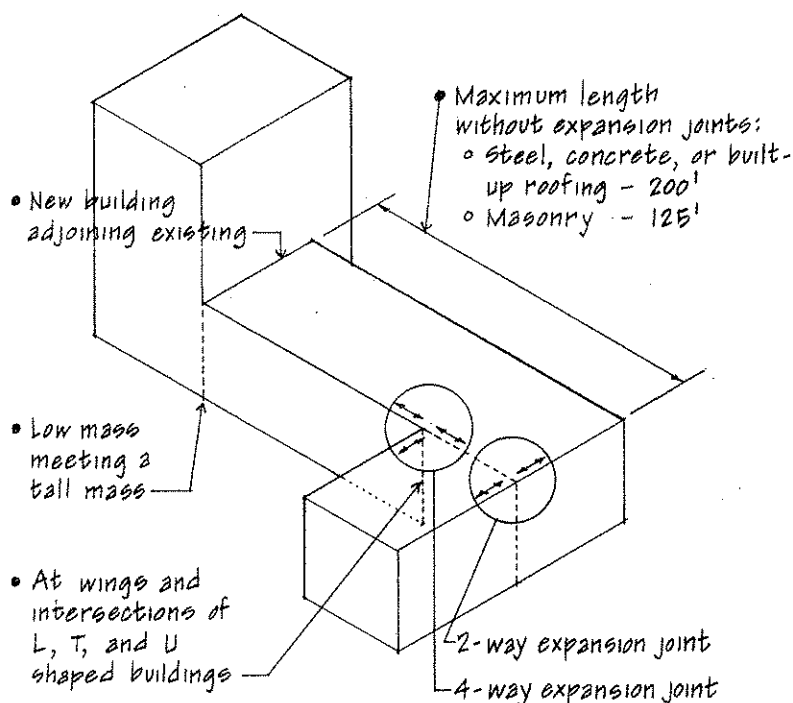
Wire mesh

Air-tight construction may require a forced ventilating system with an air-to-air heat exchanger to rid interior spaces of moisture, odors, and pollutants.



§.28 EXPANSION JOINTS

Building materials expand and contract in response to normal changes in temperature. Expansion joints allow for this thermal movement in order to prevent distortion, cracks, or breaks in the building materials. Expansion joints should provide a complete separation of material and allow free movement while, at the same time, maintain the weathertightness of the structure.



The width of an expansion joint depends on the building materials and the temperature range involved. It varies from $\frac{1}{4}$ " to 1" or more, and should be calculated for each specific situation.

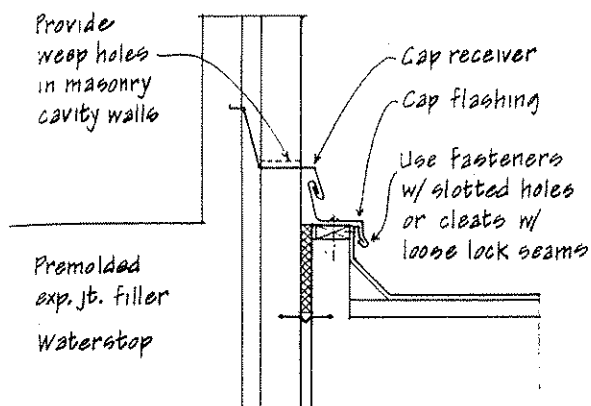
- For surfaces with severe solar exposure, expansion joints should be provided at more frequent intervals.
- Parapet walls require expansion joints near corners to prevent their displacement.
- Additional expansion joints are required in the exterior wythe of masonry cavity walls; exterior wythe must be secured to backup masonry with flexible anchors.
- Horizontal expansion joints are required at steel shelf angles in masonry walls, and above masonry walls that abut a structural frame.
- Nonbearing masonry partitions require an expansion joint when they abut a roof or floor structure that might deflect.
- Long, linear building elements, such as handrails, fascias, gravel stops, and window or curtain wall framing also require expansion joints.

COEFFICIENT OF LINEAR EXPANSION per unit length per one degree change in temperature ($^{\circ}\text{F}$)

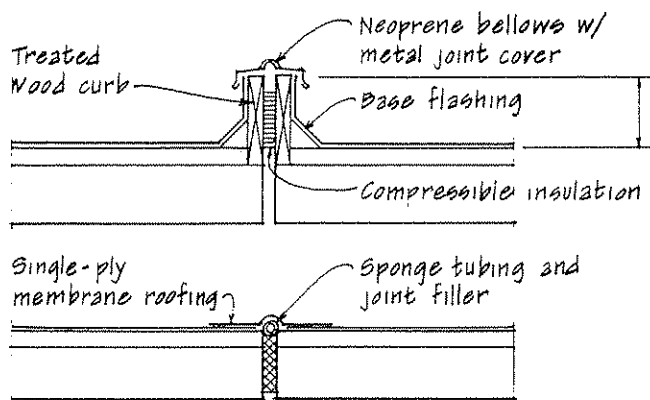
	$\times 10^{-7}$		$\times 10^{-7}$		$\times 10^{-7}$
Aluminum.....	120	Parallel to wood grain:	-	Brick masonry.....	34
Brass.....	104	Fir.....	21	Portland cement.....	70
Bronze.....	101	Maple.....	36	Concrete.....	55
Copper.....	93	Oak.....	27	Granite.....	44
Iron, cast.....	59	Pine.....	54	Limestone.....	42
Iron, wrought.....	67	Perpendicular to grain:		Marble.....	45
Lead.....	159	Fir.....	320	Plaster.....	92
Nickel.....	70	Maple.....	270	Rubble masonry.....	35
Steel, mild.....	65	Oak.....	300	Slate.....	44
Steel, stainless.....	99	Pine.....	190	Glass.....	47

Coefficient of surface expansion is approximately twice the linear coefficient.
Coefficient of volume expansion is approximately three times the linear coefficient.

EXPANSION JOINT DETAILS



EXP. JT. @ WALL AND ROOF JUNCTURE

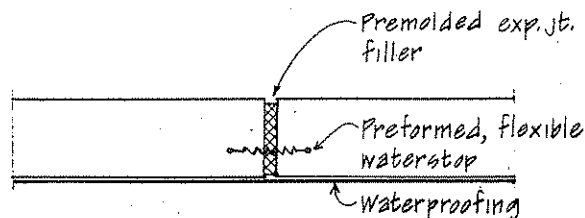


FLAT ROOF EXPANSION JOINTS

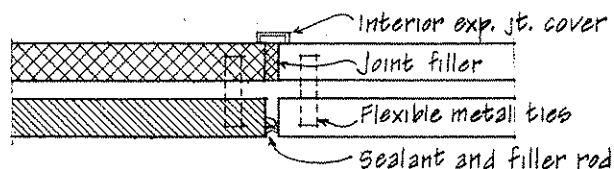
These expansion joint details, although general in nature, have the following elements in common:

- A joint A complete break through the structure which is usually filled with a compressible material.
- A weatherstop which may be in the form of:
 - An elastic joint sealant (see 8.30)
 - A flexible waterstop embedded within the construction
 - A flexible membrane over flat roof joints.

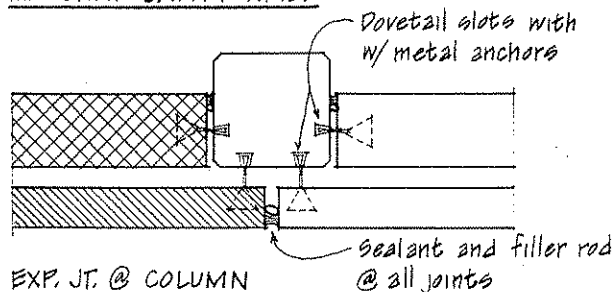
(See 5.23 for more masonry expansion joints.)



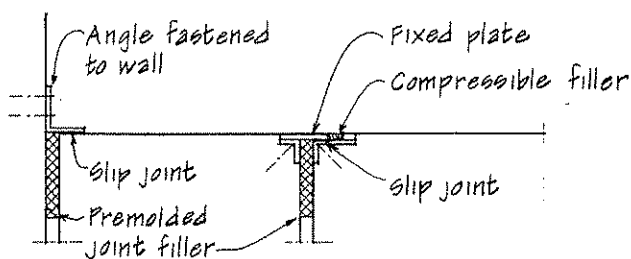
CONCRETE FOUNDATION WALL



MASONRY CAVITY WALL



EXP. JT. @ COLUMN



AT WALL

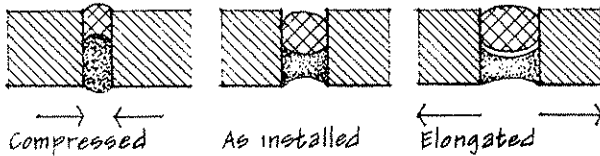
ON FLOOR

EXPANSION JOINT COVERS

Expansion joint covers are used to conceal joints in interior floor, wall, and ceiling surfaces. They usually consist of a rigid plate fixed to one side of the joint with an overlapping slip joint on the other.

§.30

JOINT SEALANTS



To provide an effective seal against the passage of water and air, a joint sealant must be durable, resilient, and have both cohesive and adhesive strength.

Sealants can be classified according to the amount of extension and compression they can withstand before failure.

• Low range sealants

- Movement capability of $\pm 5\%$
- Oil-based or acrylic compounds
- Referred to as caulking and used for small joints where little movements is expected.

• Medium range sealants

- Movement capability of $\pm 5\%$ to $\pm 10\%$
- Butyl rubber, acrylic or neoprene compounds
- Used for nonworking, mechanically fastened joints.

• High range sealants

- Movement capability of $\pm 12\%$ to $\pm 25\%$
- Polysulfides, polysulfides, polyurethanes, and silicones
- Used for working joints subject to a significant amount of movement, such as those in curtain walls.

The substrate must be clean, dry, and compatible with the sealant material.

A primer may be required to improve the adhesion of a sealant to the substrate.

The joint filler controls the depth of the sealant contact with the joining parts. It should be compressible and be compatible with but not adhere to the sealant. It may be in the form of a rod or tubing of polyethylene foam, polyurethane foam, neoprene, or butyl rubber.

When there is insufficient depth for a compressible filler, a bond breaker, such as polyethylene tape, is required to prevent adhesion between the sealant and the bottom of the joint recess.

Most sealants are viscous liquids which cure after being applied with a hand operated or power gun. These are referred to as gunnable sealants. Some lap joints, however, are difficult to seal with gunnable sealants. These joints may require instead a preformed solid tape sealant (polybutene or polyisobutylene) that is held in place under compression.

Joints should be tooled to ensure full contact with and adhesion to substrate

Sealant joint depth

Full contact depth

Sealant depth

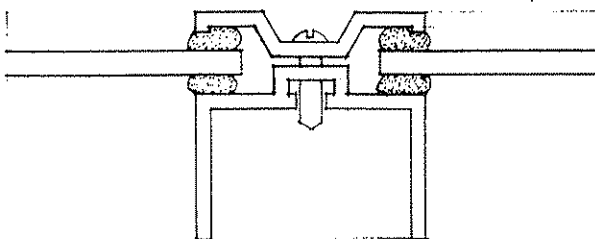
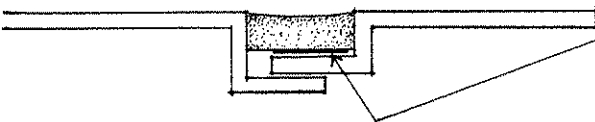
- $\frac{1}{4}$ " min. for $\frac{1}{4}$ " joints
- equal to joint width for joints up to $\frac{1}{2}$ "
- half of joint width for joints $\frac{1}{2}$ " or wider, but not more than $\frac{1}{2}$ "

Joint width = sealant width

- $\frac{1}{4}$ " to 1" or more

Width depends on:

- Joint spacing
- Expected temperature range
- Anticipated movement due to wind or structural displacement
- Movement capability of sealant



SPECIAL CONSTRUCTION

9

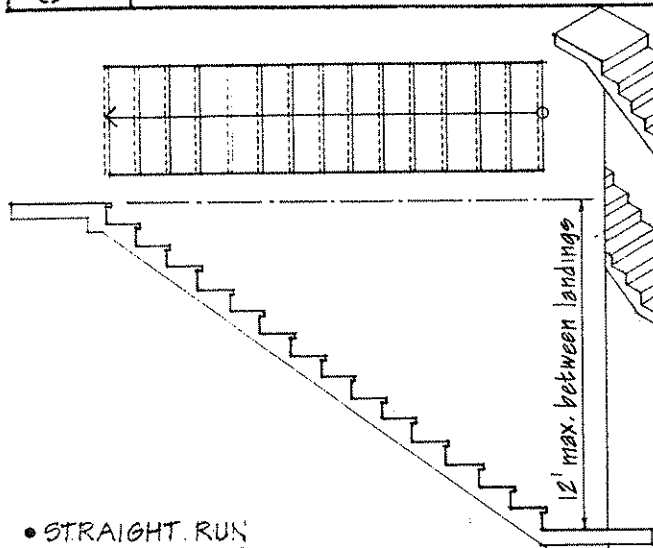
This chapter discusses those elements of a building which have unique characteristics and which therefore should be considered as separate entities. While not always affecting the exterior form of a building, they do influence the internal organization of spaces, the pattern of the structural system, and in some cases, the layout of heating, plumbing, and electrical systems.

Stairs provide means for vertical movement between stories of a building and are, therefore, important links in a building's overall circulation scheme. Whether punctuating a two-story volume of space or rising through a narrow shaft of space, a stairway takes up a significant amount of space. A stair's landings should be logically integrated with a building's structural system to avoid overly complicated framing conditions. Safety and ease of travel are, in the end, probably the most important considerations in the design and placement of stairs.

A fireplace is a source of heat and a visual point of interest for any interior space. The placement and size of a fireplace in a room should be related to the scale and use of the space. Whether it is an integral part of a wall or a freestanding element within a space, a fireplace must be constructed to draft properly. The damper and flue sizes should correspond to the size and proportions of the fireplace and precautions should be taken against fire hazards and heat loss.

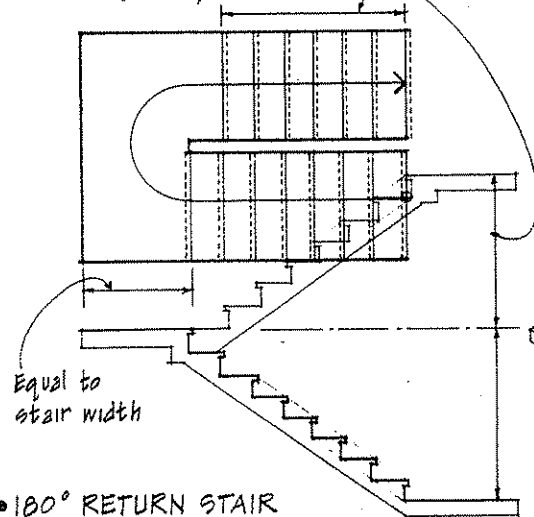
Kitchens and bathrooms are unique areas of a building that demand the careful integration of plumbing, electrical, and heating/ventilating systems with the functional and aesthetic requirements of the spaces. These areas also require special fixtures and equipment, as well as durable, easy to maintain, and sanitary surfaces and finishes.

2 STAIR PLAN TYPES

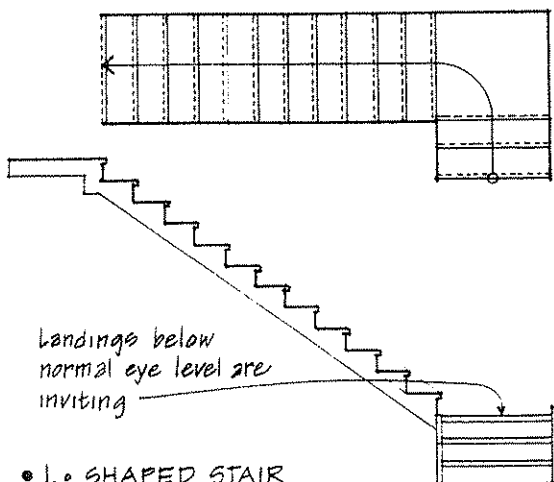


• STRAIGHT RUN

Flights may be equal or unequal



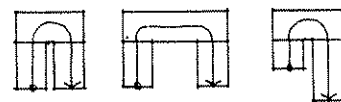
• 180° RETURN STAIR



• L-SHAPED STAIR

- Straight run stairs can be physically tiring as well as psychologically forbidding
- The building code generally limits the vertical rise between landings to 12'.
- Landings should have a dimension in the direction of travel equal to the width of the stair, but it need not exceed 4'.
- A stairway may be approached and departed either axially or perpendicular to the stair run.
- The form and placement of a stair are related to the circulation scheme for the building and the spatial configuration of the area in which the stair is located.

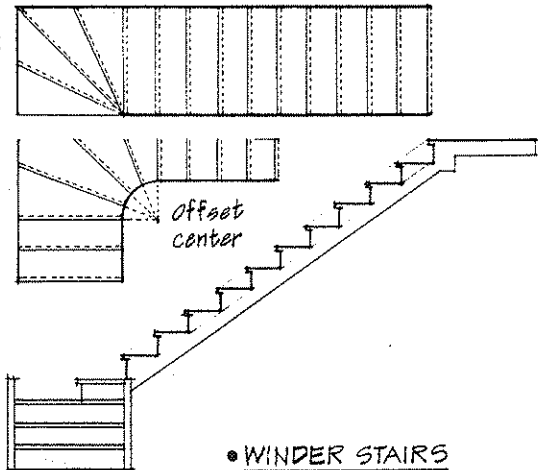
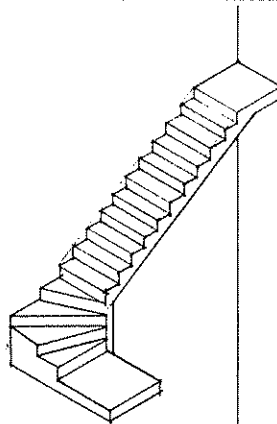
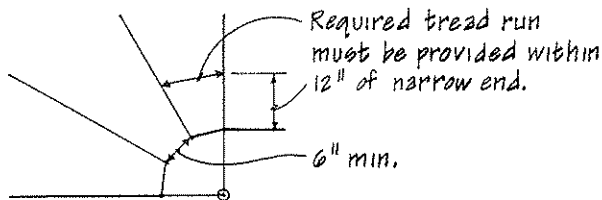
- A 180° return stair is more compact than a single straight run stair.
- It may occupy a square or rectangular area in plan depending on the widths and runs of its two flights.



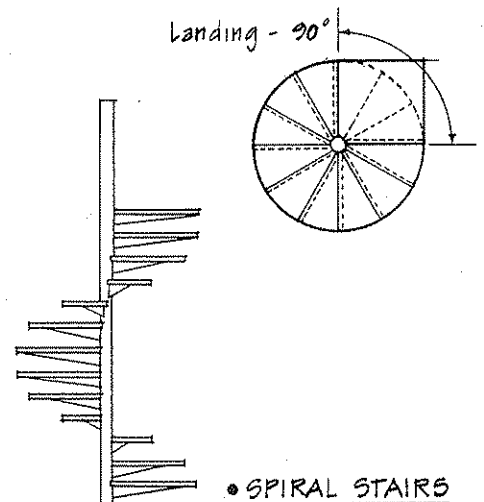
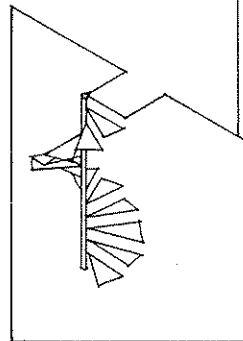
- An L-shaped stair may have either equal or unequal flights, depending on the desired proportion of the stairway opening.
- It may also be extended into a U-shape with three flights of stairs.



- Winders refer to the triangular treads which are used to conserve space when a stairway changes direction.
- Winders can be hazardous since they offer little foothold at their interior corners.
- The building code generally restricts the use of winders to certain residential occupancies and specifies the minimum tread run.



- Spiral stairs occupy a minimum amount of space in plan.
- They are used in residences and for access to loft spaces.
- Residential spiral stairs may be used as required exits if the area served is limited to 400 S.F.
- See 9.10 for typical dimensions.



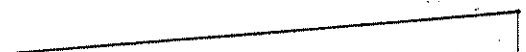
• RAMPS

Ramps provide smooth transitions between the floor levels of a building. To have comfortably low slopes, they require relatively long runs. They are typically used to provide

Access for the handicapped
Access for wheeled equipment
Smooth, continuous movement through or around a tall space.

Short, straight ramps act as beams and may be constructed as wood, steel, or concrete floor systems. Long or curvilinear ramps are usually of steel or reinforced concrete.

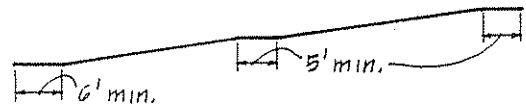
Ramps should have nonslip surfaces, especially when exposed to the weather.



1:12 max. slope for handicapped access and when ramp is used as an emergency exit

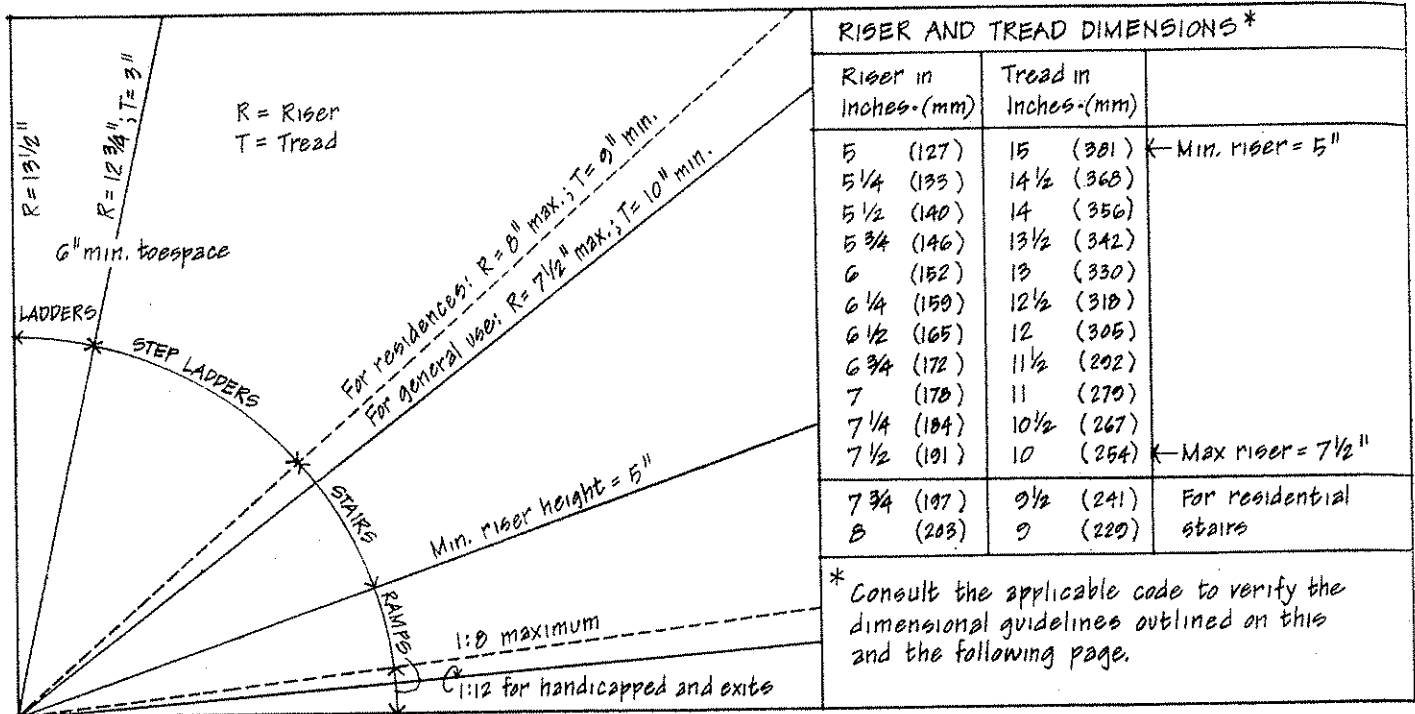


1:8 max. for other ramps



Landings are required at the top and bottom, and for each 5' of rise.

4 STAIR RISER AND TREAD DIMENSIONS



The dimensions of a stair's risers and treads should be proportioned to accommodate our body movement. Their pitch, if steep, can make ascent physically tiring as well as psychologically forbidding, and can make descent precarious. If a stair's pitch is shallow, its treads should be deep enough to fit our stride.

Building codes regulate the minimum and maximum dimensions of risers and treads. Some codes specify a maximum riser dimension of 7 1/2" and a minimum tread of 10"; others limit a riser to 7" and require a tread of at least 11". Residential stairs are usually allowed to have 8" risers and 9" treads.

For comfort, the riser and tread dimensions can be proportioned according to the following formula:

$$(2 \times \text{riser}) + \text{tread} = 24 \text{ to } 25 \text{ (inches)} \quad \leftarrow$$

Exterior stairs are generally not as steep as interior stairs, especially where dangerous conditions such as snow and ice exist. The proportioning formula can therefore be adjusted to yield a sum of 26.

For safety, all risers in a flight of stairs should be the same height and all treads should have the same run. Building codes limit the allowable variation in riser height or tread run to 3/16."

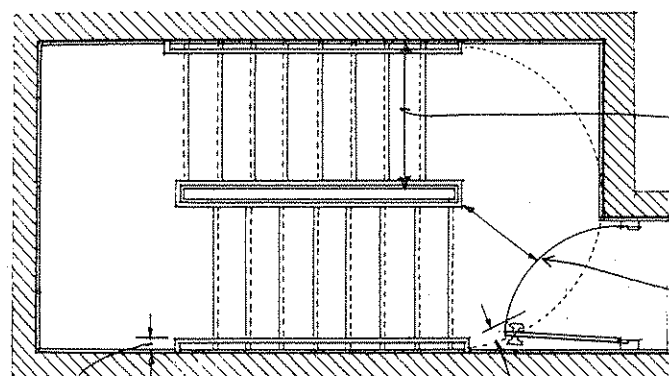
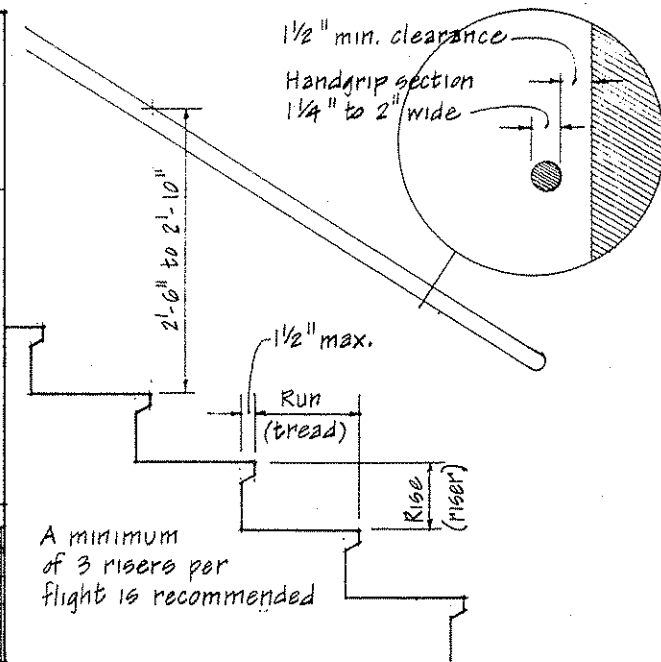
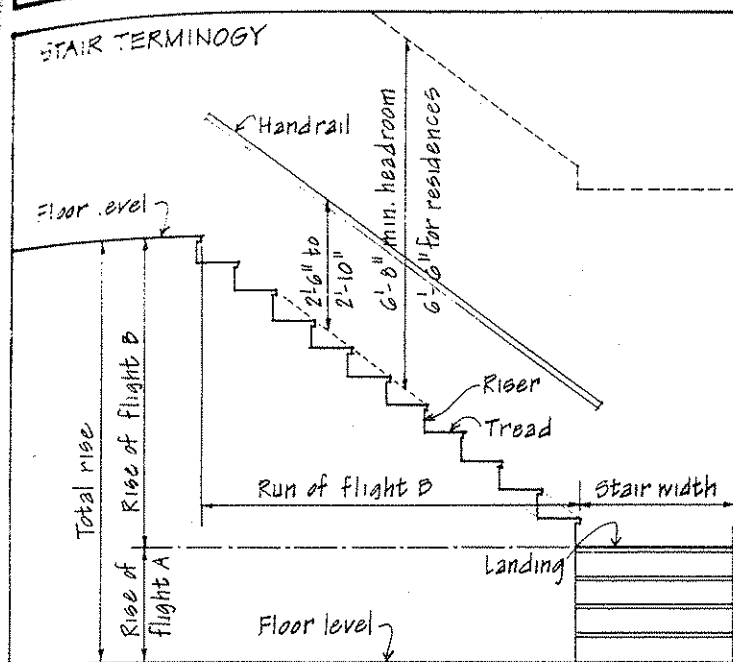
The actual riser and tread dimensions for a set of stairs are determined by dividing the total rise (the floor-to-floor height) by the desired riser height. The result is rounded off to arrive at a whole number of risers. The total rise is then redivided by this whole number to arrive at the actual riser height.

This riser height must be checked against the maximum riser height allowed by the building code. If necessary, the number of risers can be increased by one and the actual riser height recalculated.

Once the actual riser height is fixed, the tread run can be determined by using the riser: tread proportioning formula.

Since in any flight of stairs, there is always one less tread than the number of risers, the total number of treads and the total run can easily be determined.

STAIR REQUIREMENTS



Building codes base the required width of a stair on the type of occupancy and the occupant load served.

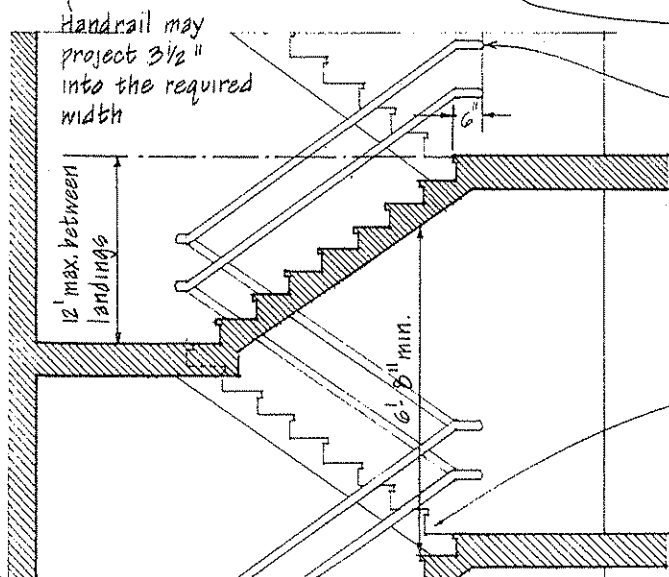
Min. width	Occupant load (OL)
2'-0"	Private stairway; OL < 10
3'-0"	OL ≤ 50
3'-0"	OL > 50

Door should swing in direction of exit. Door swing must not reduce the landing width to less than one half of its required width.

When fully open, the door must not intrude into required width by more than 3 1/2".

Except for residential stairways and stairways less than 3'-0" in width, handrails are required on both sides of the stair. At least one handrail should extend beyond the top and bottom risers at least 6". The ends should return to a wall or terminate in a newel post.

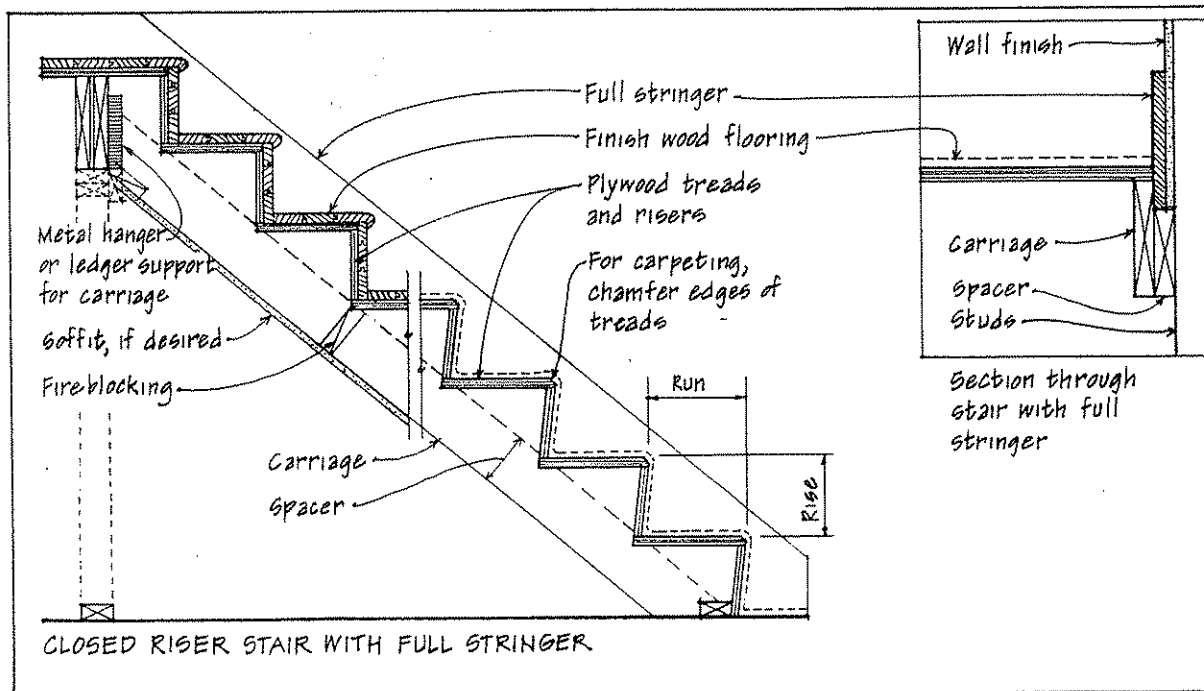
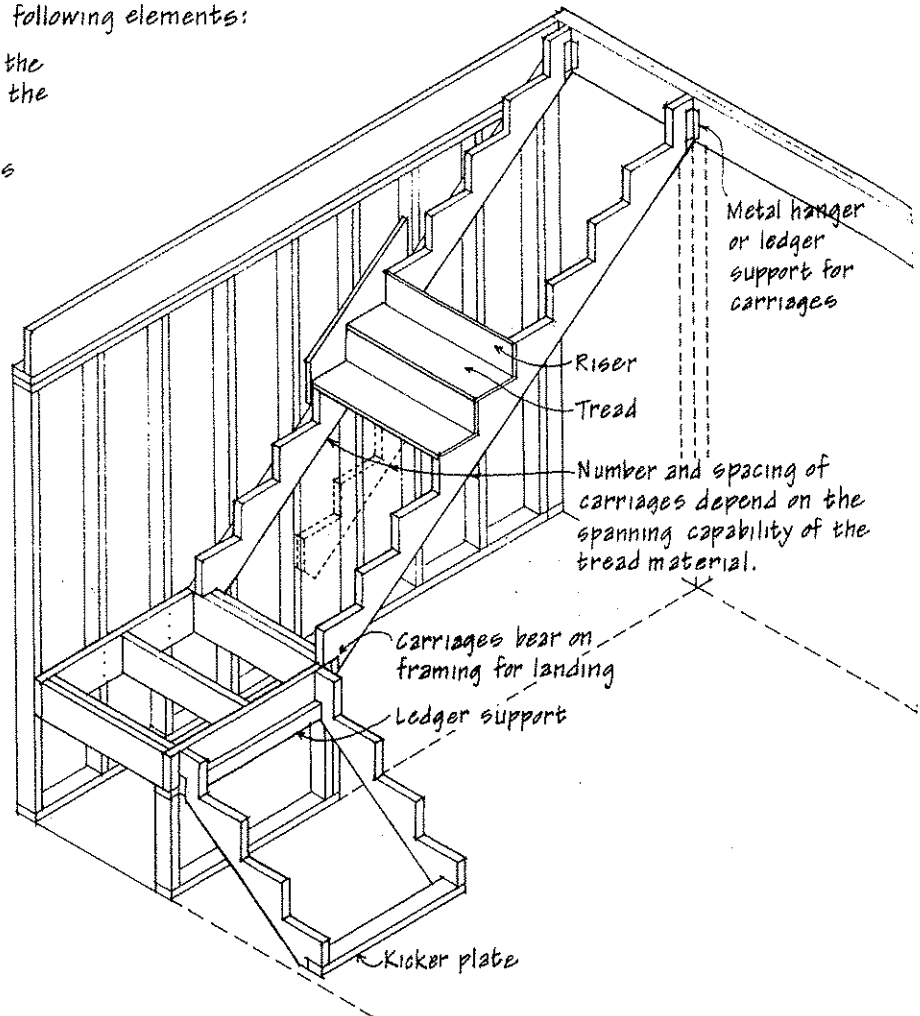
Offsetting the risers at a landing can enable the handrail to turn without a pronounced vertical drop.

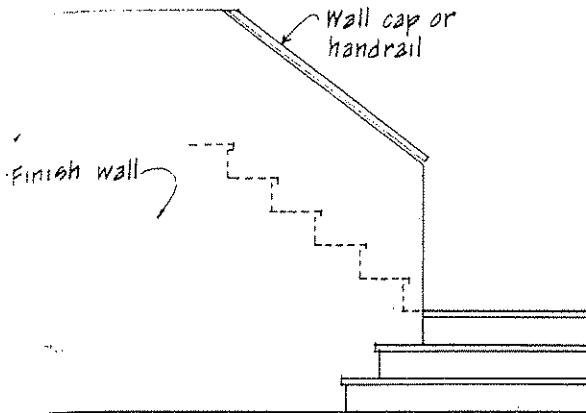


9.6 WOOD STAIRS

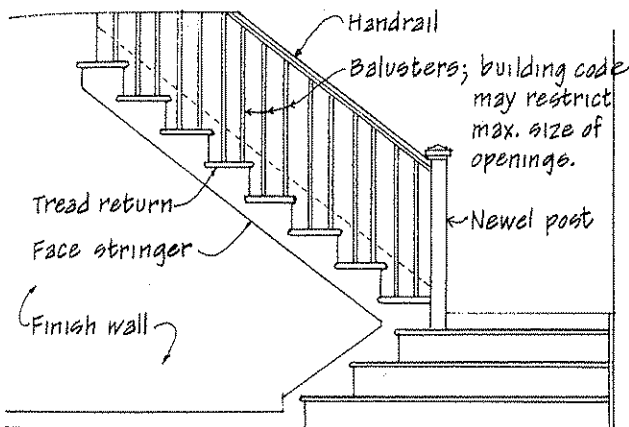
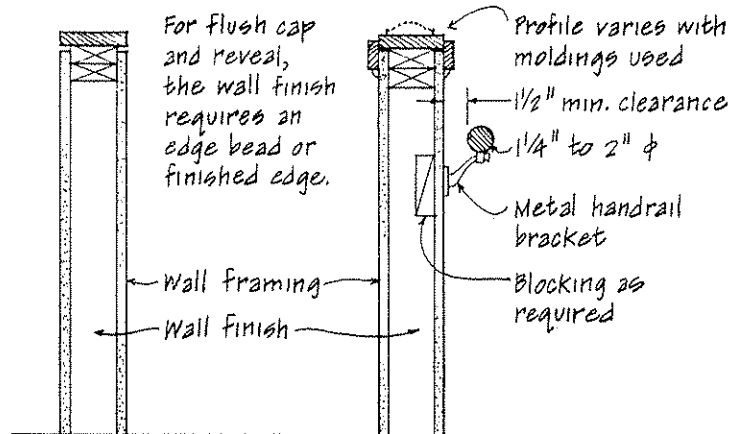
A wood stair is constructed of the following elements:

- Carriages, or rough stringers, are the main framing members that support the stair treads and risers.
- Stringers are the sloping side boards against which the risers and treads terminate; they are usually finish members although some are housed to serve as a carriage and support the risers and treads.
- Treads are the footways that span the distance between the carriages.
- Risers are vertical boards that close off the stair space and help make the construction rigid; some stairs have no risers.

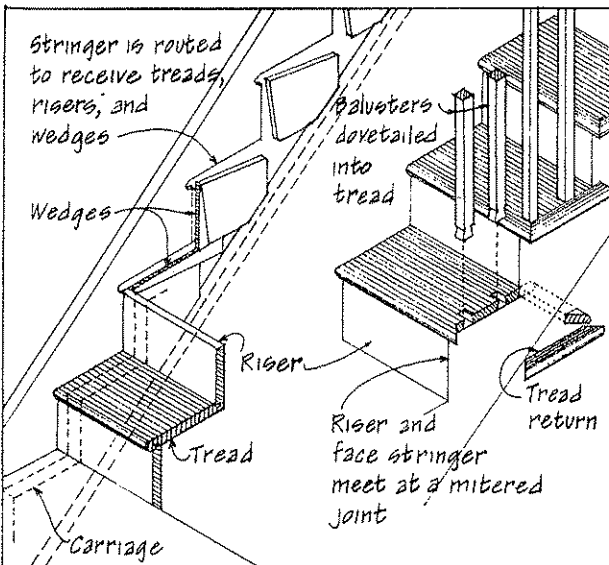
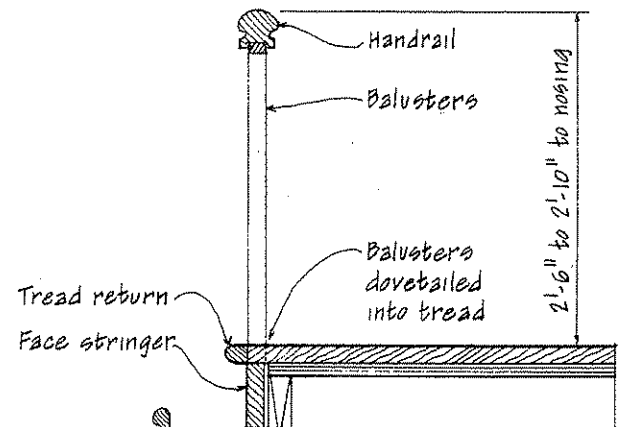




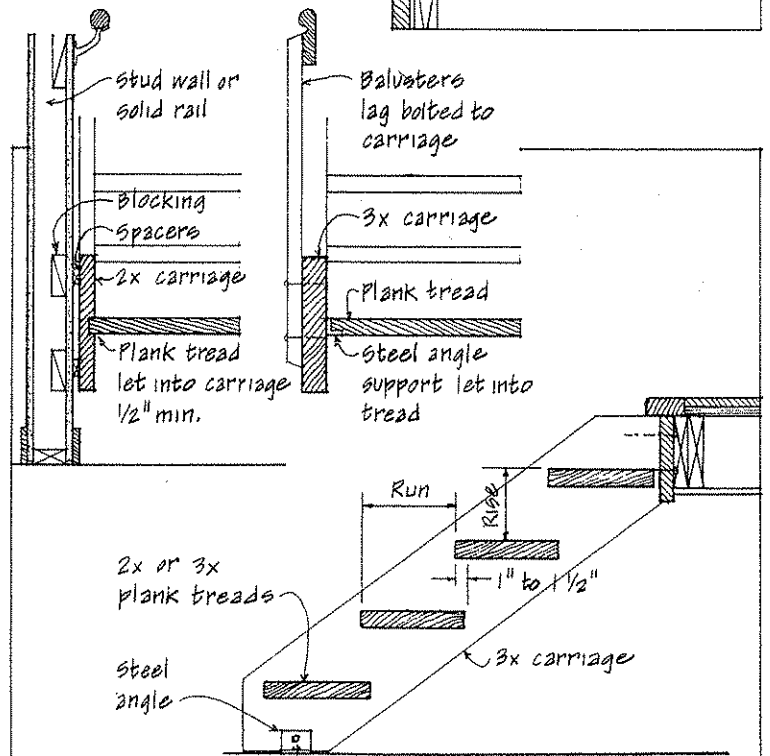
SOLID RAILING



OPEN RAILING



CLOSED RISER STAIR WITH HOUSED STRINGER



OPEN RISER STAIR

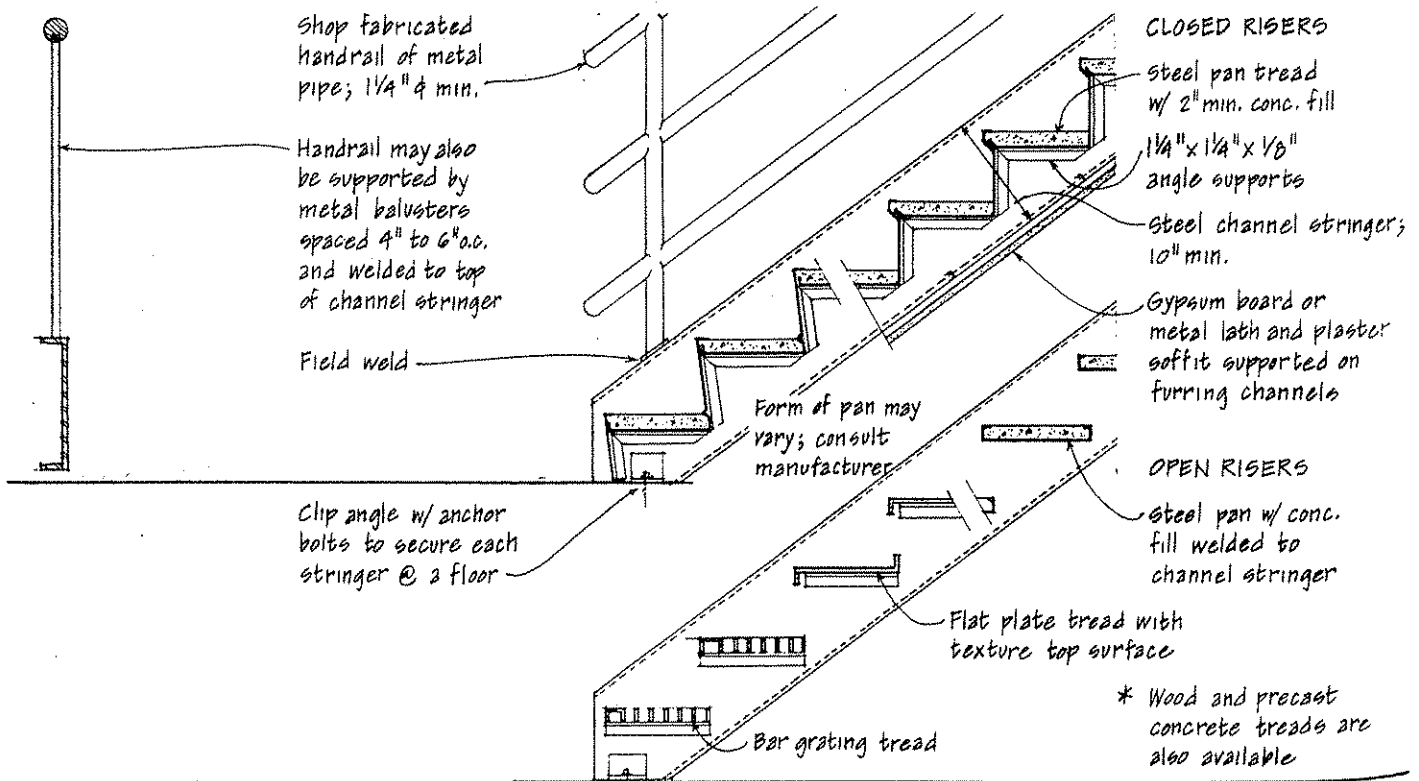
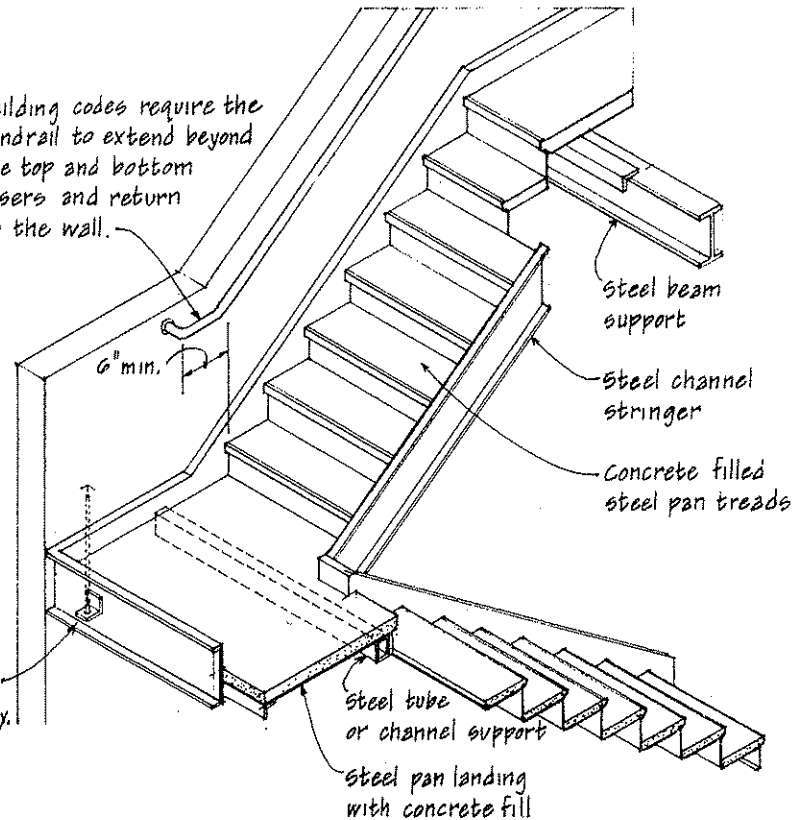
9.8 STEEL STAIRS

Steel stairs are analogous in form to wood stairs.

- Steel channel sections serve as the stringers
- The stair treads span the distance between the stringers; they are usually in the form of steel pans filled with concrete.
- Steel treads may also consist of bar grating or flat plates with a textured top surface; these tread types are used in utility stairs.
- Pre-engineered and prefabricated steel stairs are available.

Building codes require the handrail to extend beyond the top and bottom risers and return to the wall.

Steel channel support for landing may be hung with threaded rods from the floor structure above, or bear directly on masonry.

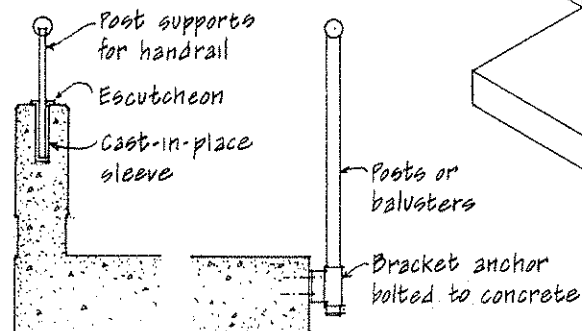
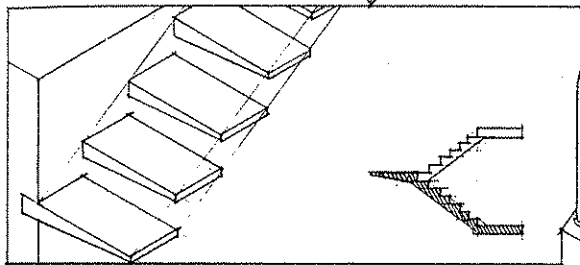


CONCRETE STAIRS

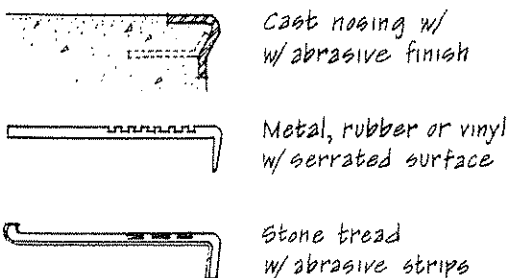
A concrete stair is designed as an inclined, one-way reinforced slab with steps formed on its upper surface. If the stair is constructed after the floor beam or wall supports, it acts as a simple beam. If it is cast with the beam or slab supports, it is designed as a continuous beam.

Concrete stairs require careful analysis of load, span, and support conditions. Consult a structural engineer.

With reinforced concrete, a variety of cantilevered designs can be formed and constructed. In addition, precast concrete stair elements are available.



Handrail supports may be anchored to the top of the stair slab or low wall, or to the slab edge.



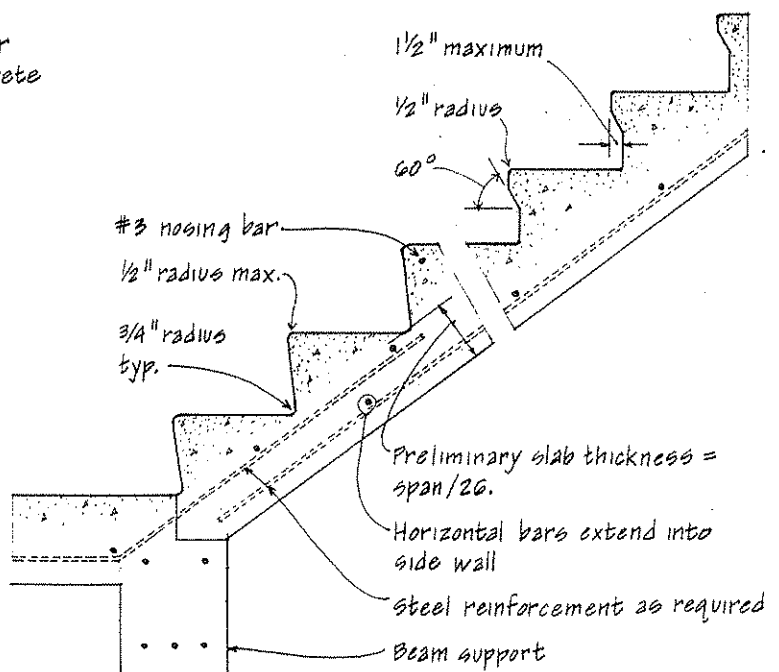
Concrete stairs require slip resistant nosings and treads.

Edge of slab may be turned up to form a curb or solid railing

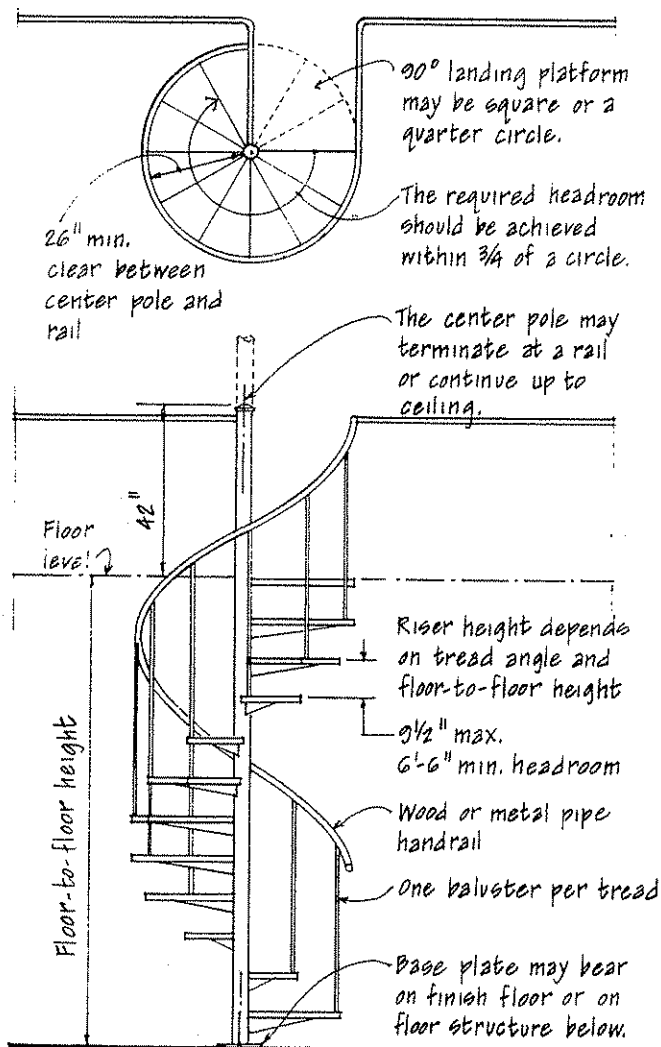
1/2" min. @ conc. walls; 4" min. @ masonry walls

Stair slab thickness; preliminary estimate = $\text{span}/26$.

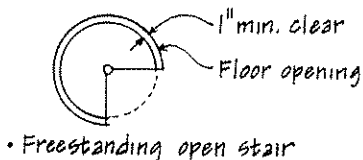
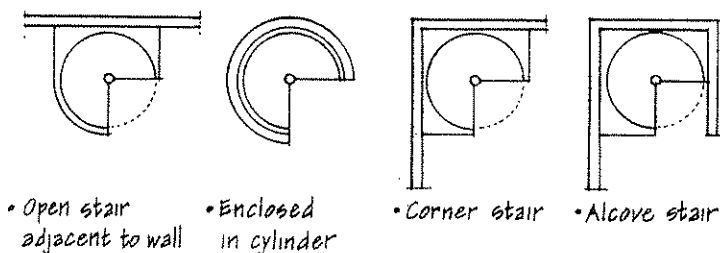
Span is equal to the horizontal distance between the slab supports.



10 SPIRAL STAIRS

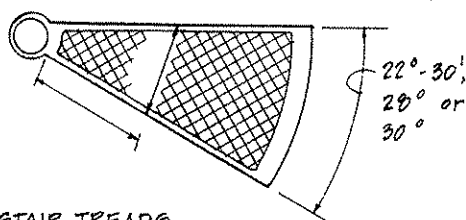


PLAN AND ELEVATION



Various connections are available to anchor the platform to the floor structure.

POSSIBLE STAIR LOCATIONS



STAIR TREADS

Metal treads may be of steel or aluminum.

- Checkered plate
- Abrasive coated plate
- Bar grating
- Steel pan with concrete or terrazzo fill

Wood treads require a steel substructure.

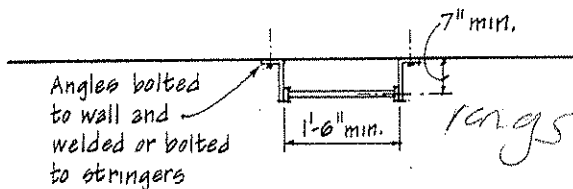
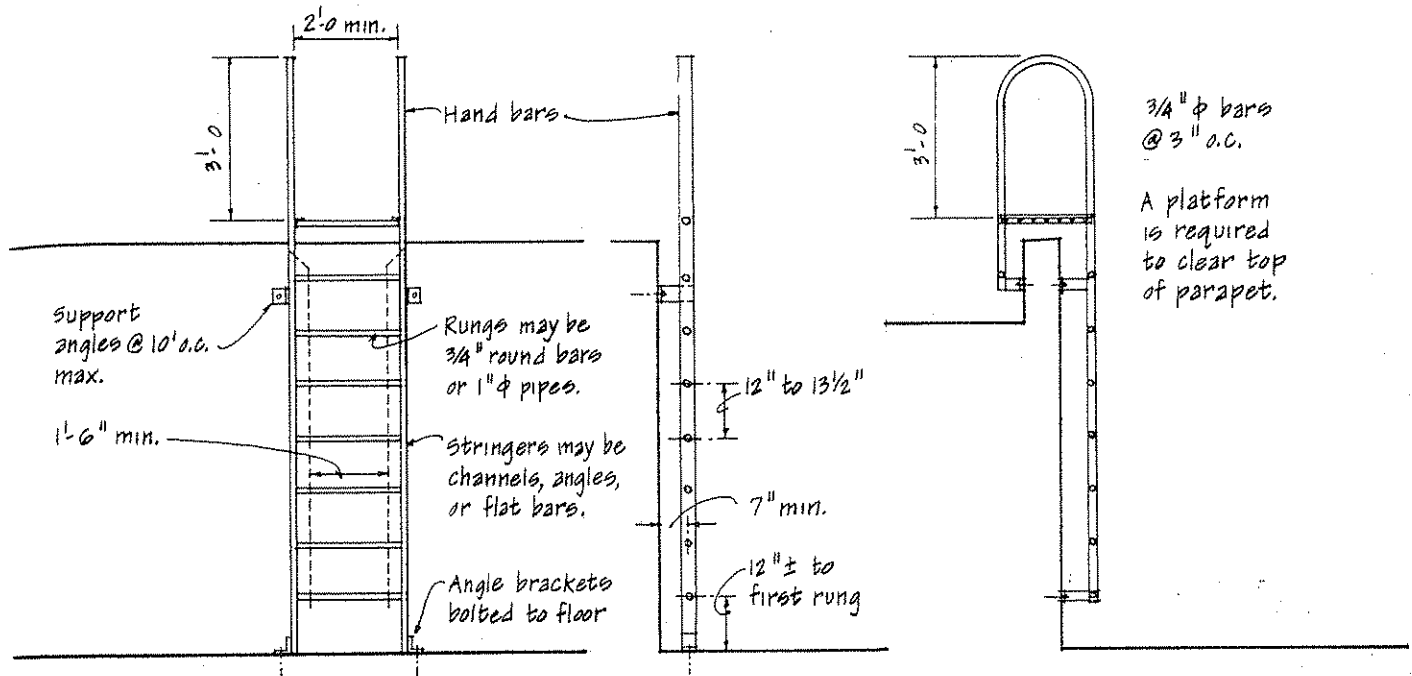
- Hardwood tread
- Plywood for carpeted treads

REPRESENTATIVE SIZES AND DIMENSIONS OF SPIRAL STAIRS *

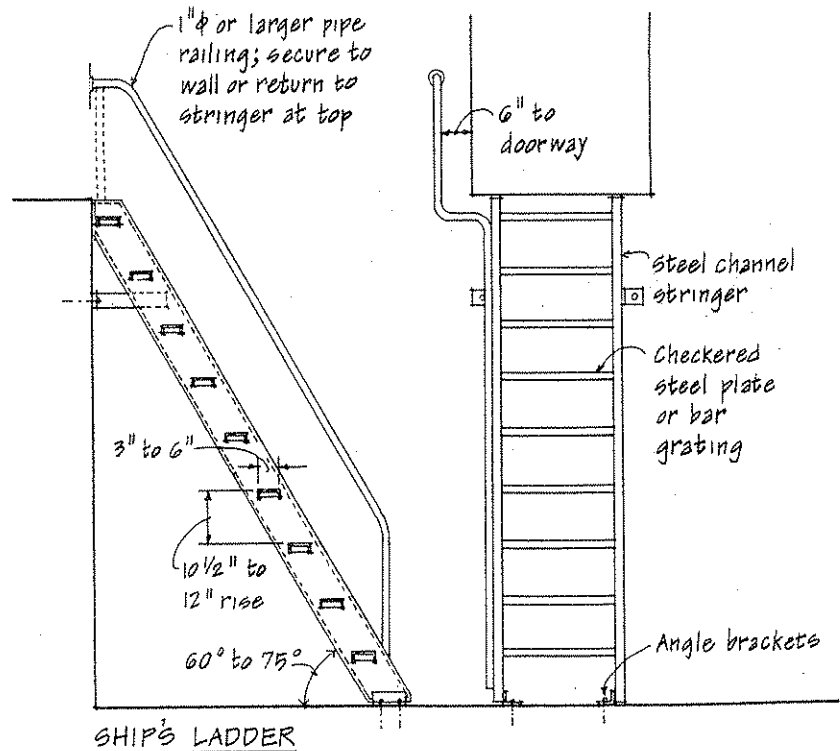
Tread angle	Nº of treads in a circle	Riser height	Headroom	Stair diameter	Well opening	Platform size	Width: Pole to rail	Center pole/ base plate diameter
22°-30°	16	7"	7'-0"	60"	64"	31"	26"	4" - 12"
28°	12-13	7½"-7¾"	6'-9"	66"	70"	34"	28"	4" - 12"
30°	12	8½"-9"	6'-9"	72"	76"	37"	31½"	4" - 12"
				78"	82"	40"	34½"	4" - 12"
				84"	88"	43"	37½"	6" - 12"
				90"	94"	46"	40½"	6" - 12"
				96"	100"	49"	43½"	6" - 12"

* Consult manufacturer's literature to confirm the dimensional guidelines contained in these tables.

LADDERS



VERTICAL LADDERS



Ladders are used primarily in industrial construction and in utility and service areas. They may also be used in private residential construction where space is extremely tight and traffic is minimal.

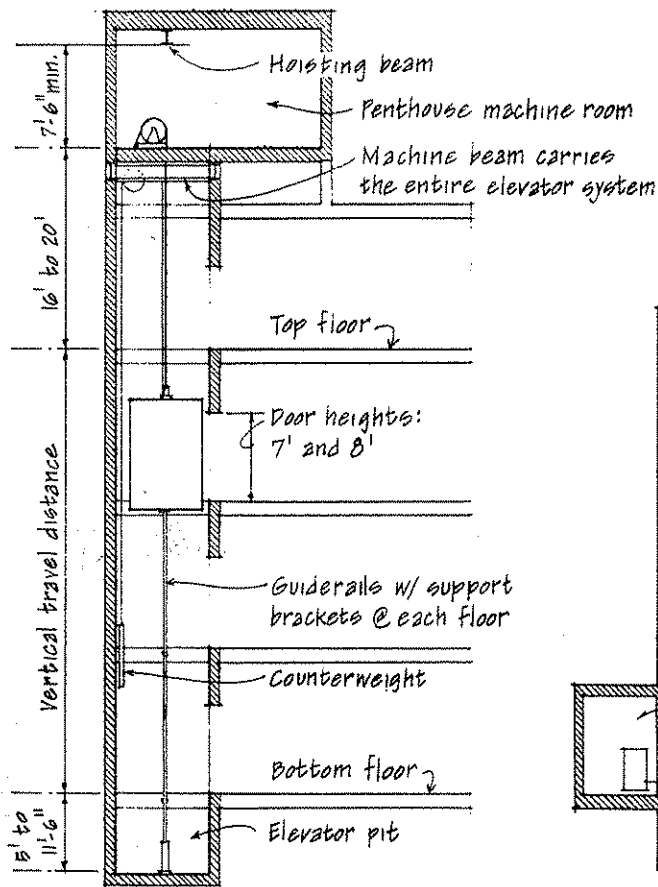
The drawings on this page illustrate ladders built with metal components. The ladder forms may be translated into wood construction.

Safety considerations include:

- Proper riser height
- Adequate toe space
- Adequate support for strings and railings
- Slip-resistant treads

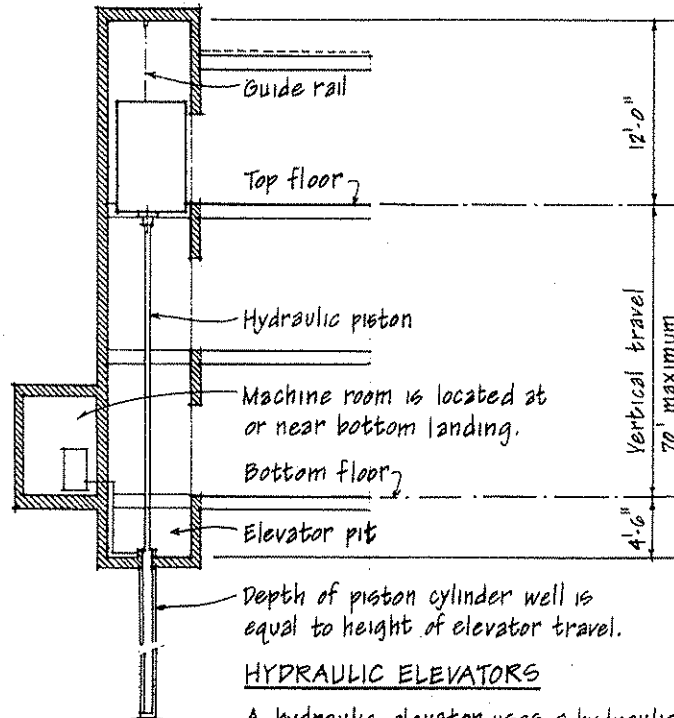
SHIP'S LADDER

12 ELEVATORS



Elevators are means of direct, vertical travel for a building's occupants, equipment, and supplies. The type, size, number, and arrangement of elevators required are determined by:

- Type of occupancy
- Amount and tempo of traffic to be carried
- Total vertical travel distance
- Average round-trip time and elevator speed desired.



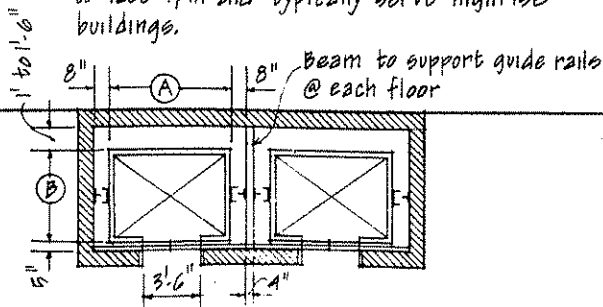
ELECTRIC ELEVATORS

Electric-powered elevators require a penthouse to accommodate hoisting and control equipment. Geared traction elevators are capable of speeds up to 350 fpm and are suitable for medium-rise buildings. Gearless traction elevators are available with speeds up to 1200 fpm and typically serve high-rise buildings.

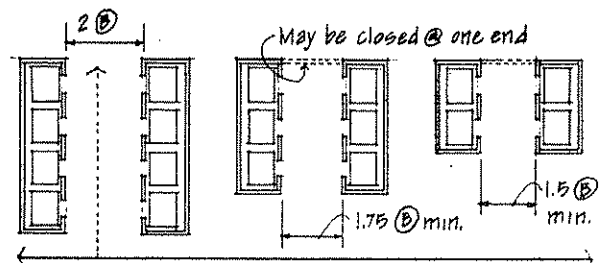
HYDRAULIC ELEVATORS

A hydraulic elevator uses a hydraulic piston to raise and lower the elevator cab. It does not require a penthouse but its lower speed and piston length limit its use to buildings up to six stories in height.

- These guidelines are for preliminary planning only. Consult the local code and the elevator manufacturer for size and structural requirements as well as shaftway requirements for fire separation, ventilation, and soundproofing.



Rated Load	(A)	(B)
2500 lbs.	6'-8" to 7'-0"	4'-2" to 5'-0"
3000 lbs.	6'-8" to 7'-0"	4'-8" to 5'-6"
3500 lbs.	6'-8" to 7'-0"	5'-6" to 6'-2"

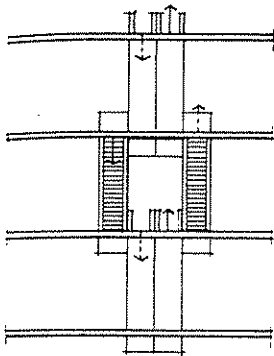


Elevator banks are normally placed off of the main circulation path.

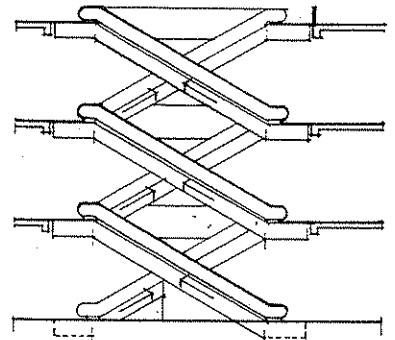
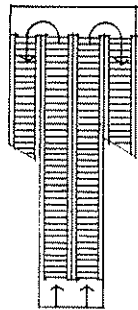
ESCALATORS

9.15

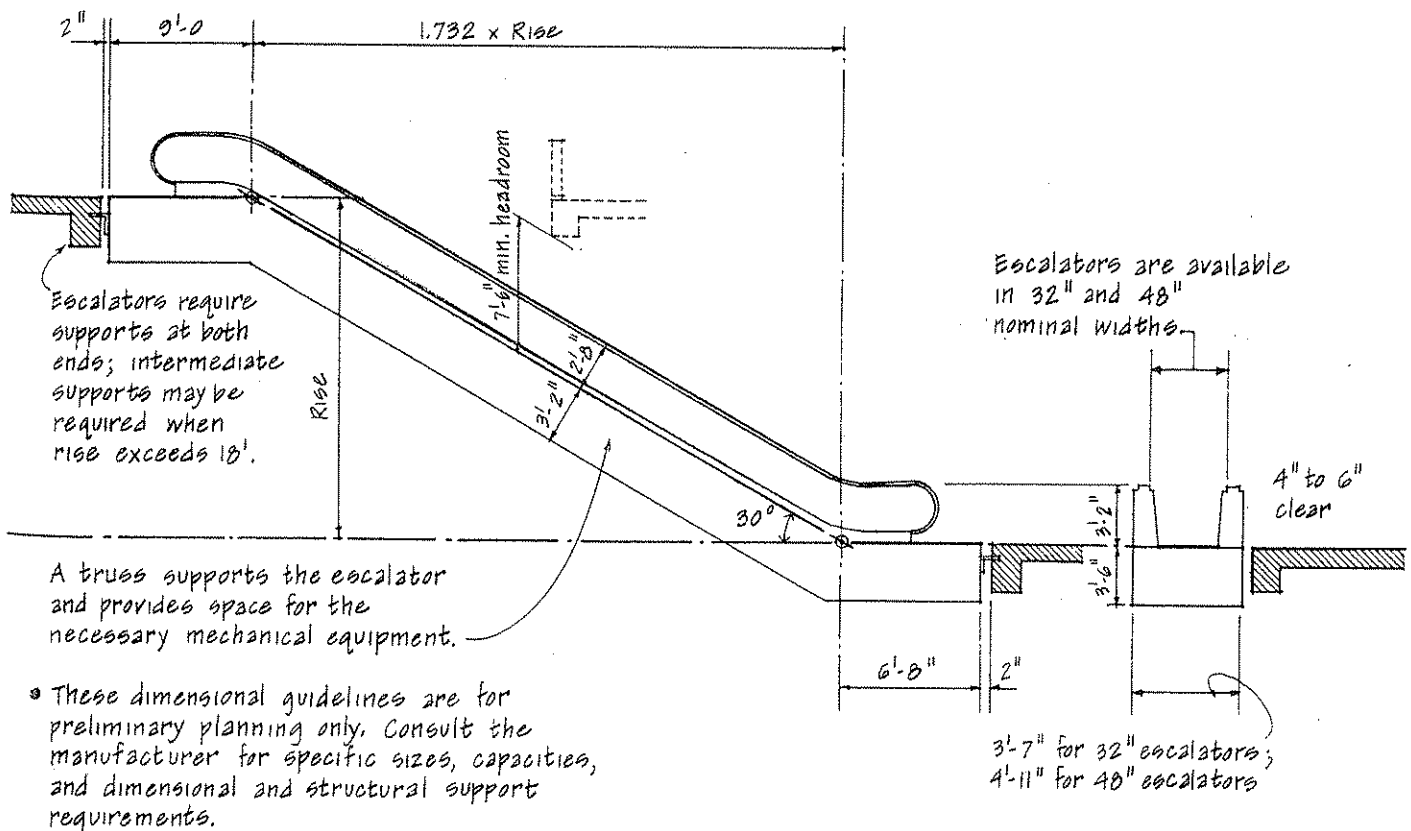
Escalators can move a large number of people efficiently and comfortably among a limited number of floors. Six floors are a practical limit. Because escalators move at a constant speed, there is practically no waiting period, but there should be adequate queuing space at each loading and discharge point. Escalators cannot be used as required exits.



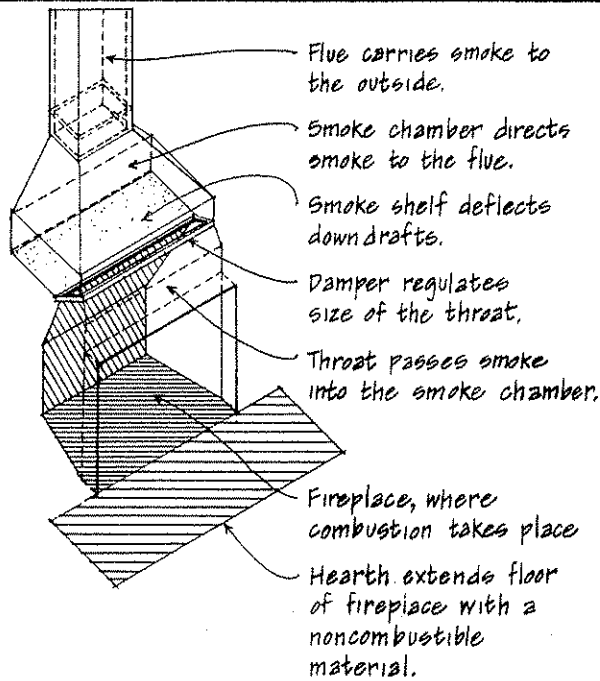
PARALLEL ARRANGEMENT



CRISSCROSS ARRANGEMENT



14 FIREPLACES

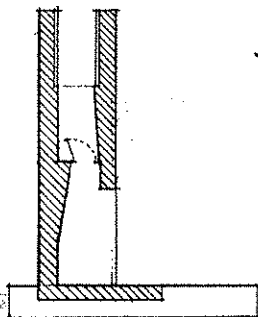


A fireplace should be designed and constructed to:

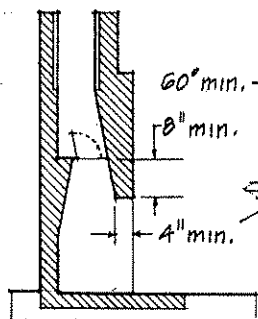
- Sustain the combustion of the fuel
- Draw properly to carry smoke and other combustible by-products to the outside
- Radiate the maximum amount of heat comfortably into the room
- Ensure proper distances from combustible materials.

Thus the dimensions and proportions of a fireplace and its flue, and the arrangement of its components, are subject to the laws of nature and the requirements of the building and mechanical codes.

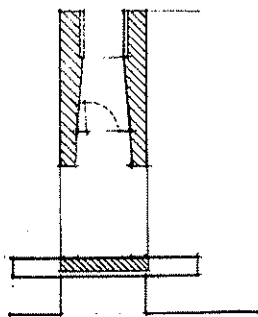
The table below provides typical dimensions for three types of fireplaces.



OPEN FRONT



OPEN FRONT AND SIDE



OPEN FRONT AND BACK

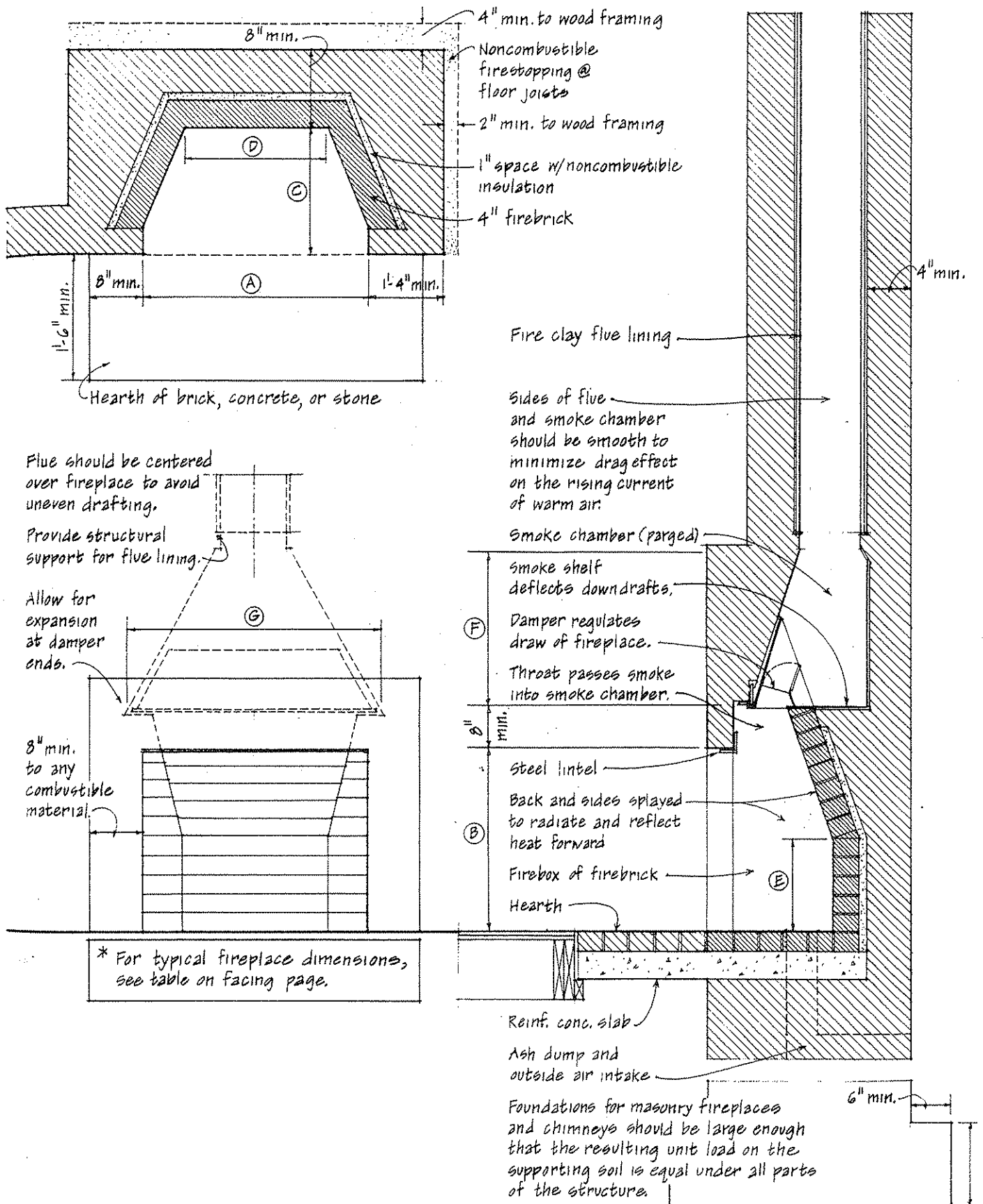
Multifaced fireplaces are especially susceptible to drafts in a room; avoid placing their openings opposite an exterior door.

TYPICAL FIREPLACE DIMENSIONS (inches)

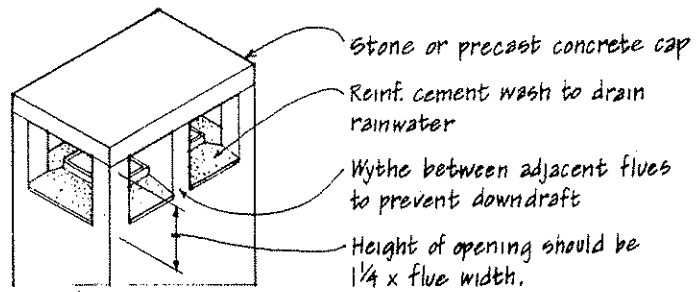
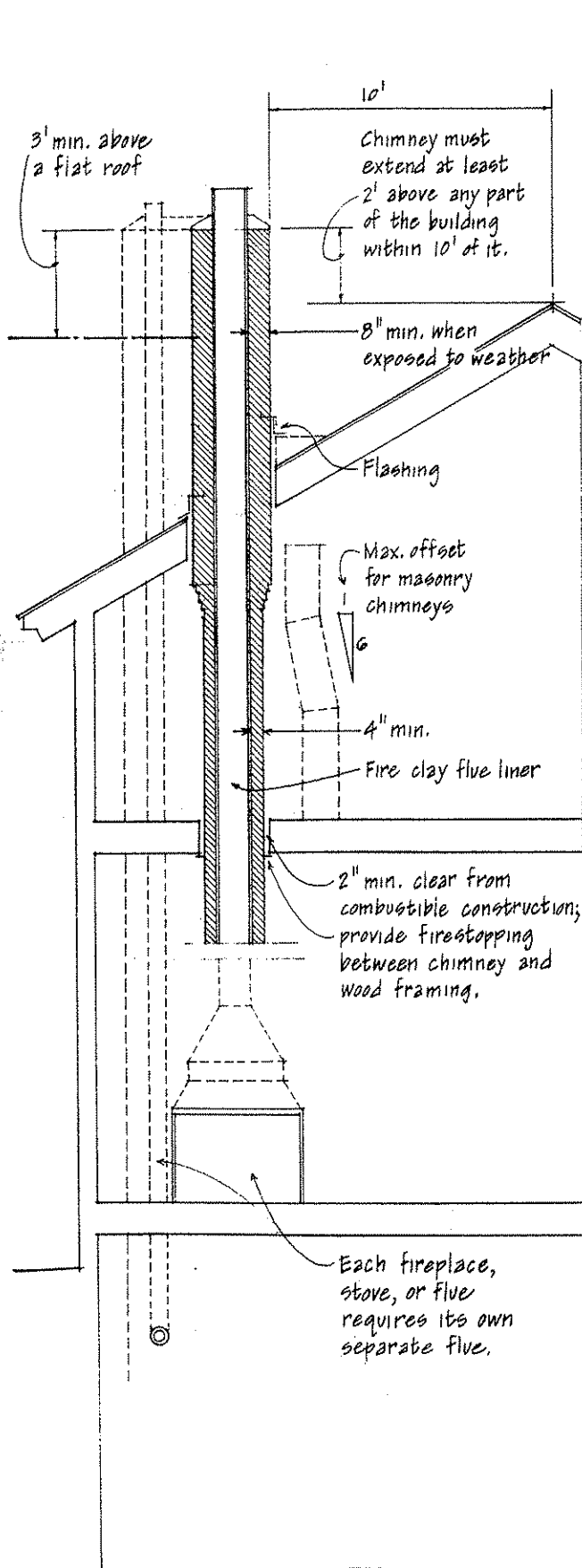
Width (A)	Height (B)	Depth (C)	Back width (D)	Vertical back (E)	Smoke chamber (F)	Damper width (G)	Flue size
OPEN FRONT							
24	24	16	11	14	10	32	8 x 12
28	24	16	15	14	21	36	8 x 12
32	29	16	19	14	24	40	12 x 12
36	29	16	23	14	27	44	12 x 12
42	32	16	29	14	32	50	16 x 16
48	32	18	33	14	37	56	16 x 16
54	37	20	37	16	45	60	16 x 16
60	40	22	42	16	45	72	16 x 20
72	40	22	54	16	56	84	20 x 20
OPEN FRONT AND SIDE							
28	24	16					12 x 12
32	28	18					12 x 16
36	30	20					12 x 16
48	32	22					16 x 16
OPEN FRONT AND BACK							
28	24	16					12 x 12
32	28	16					12 x 16
36	30	17					12 x 16
48	32	19					16 x 16

FIREPLACE REQUIREMENTS

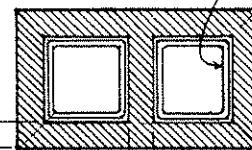
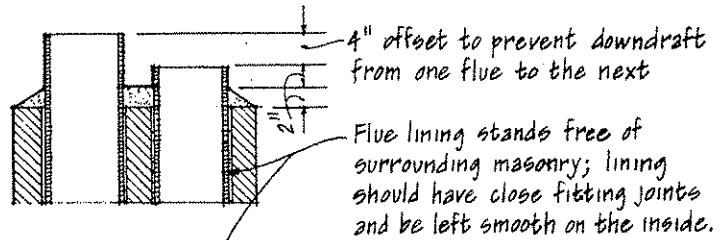
9.15



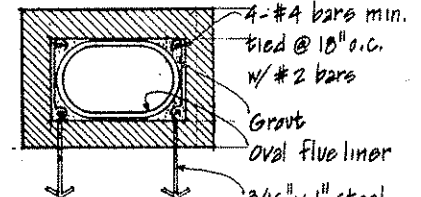
16 MASONRY CHIMNEYS



CHIMNEY HOOD



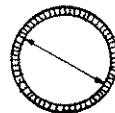
- Consult building or mechanical code for chimney requirements of high heat appliances such as incinerators.



- In seismic zones, masonry chimneys require reinforcing and anchorage to the building's structural frame. Consult local code.

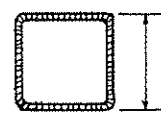
MINIMUM FLUE SIZES

- Square or rectangular: 1/10 th of fireplace opening
- Round: 1/12 th of fireplace opening



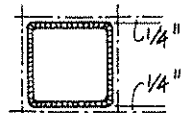
Size = inside ϕ

ROUND



outside faces

RECTANGULAR

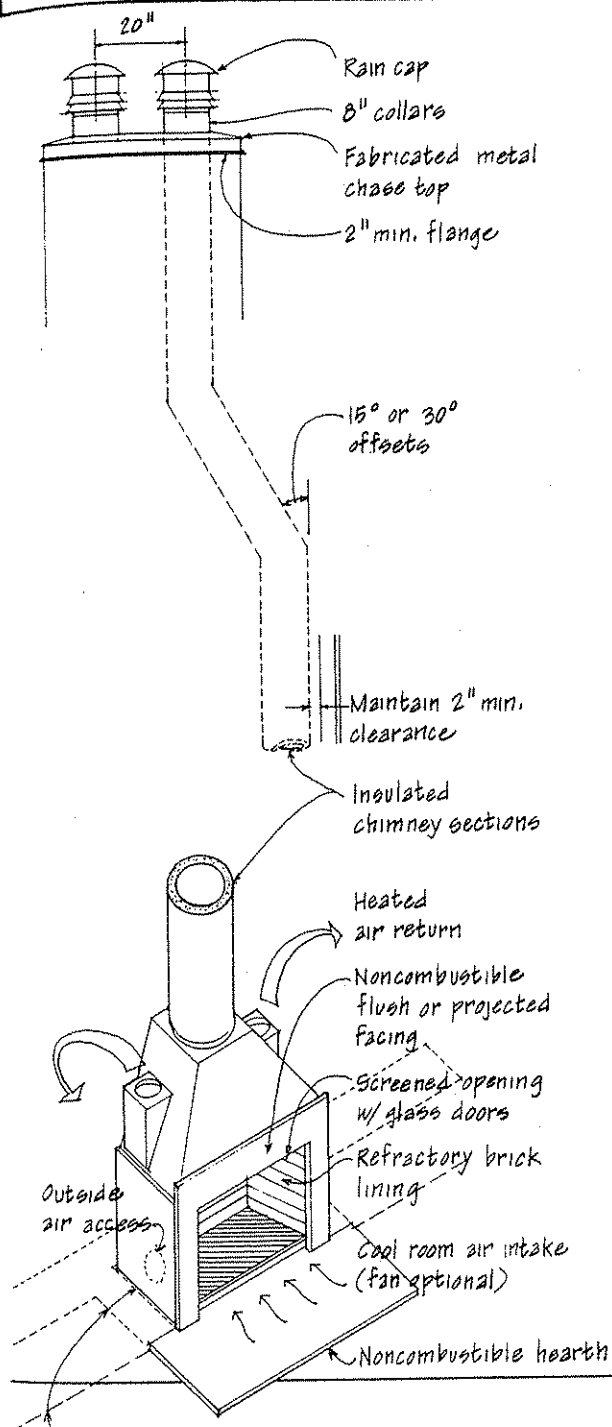


Size = actual + 1/2"

MODULAR

Size (in.)	Area (sq.in.)	Size (in.)	Area (sq.in.)	Size (in.)	Area (sq.in.)
8"	47	8 1/2" x 8 1/2"	51	8" x 12"	57
10"	74	8 1/2" x 13"	79	12" x 12"	87
12"	108	13" x 13"	125	12" x 16"	120
15"	171	13" x 18"	168	16" x 16"	162
18"	240	18" x 18"	232	16" x 20"	208
20"	298	20" x 20"	279	20" x 20"	262
24"	433	20" x 24"	338	20" x 24"	320
		24" x 24"	420	24" x 24"	385

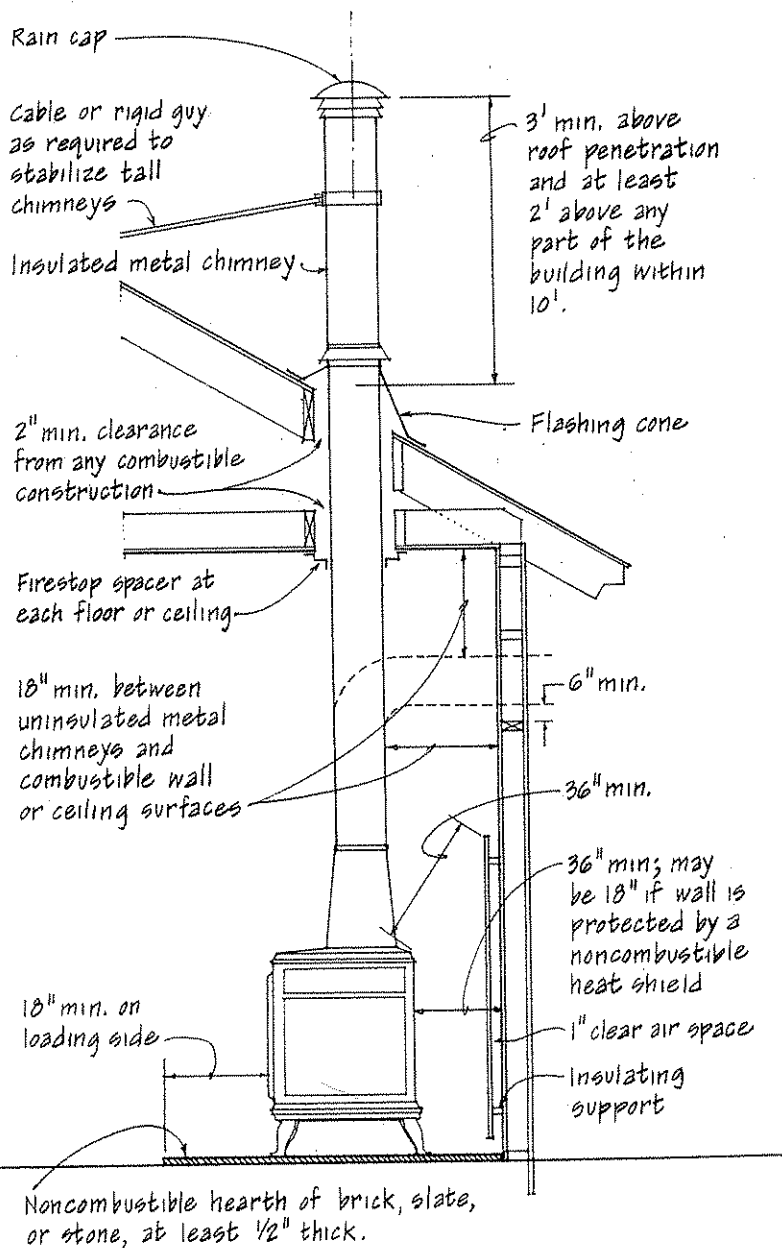
PREFABRICATED FIREPLACES AND STOVES



Zero-clearance models have insulated shells and may be installed against combustible framing.

Typical widths: 36", 38", 42", 46", 48", 54"
 Typical heights: 30", 32", 36"
 Typical depth: 24"

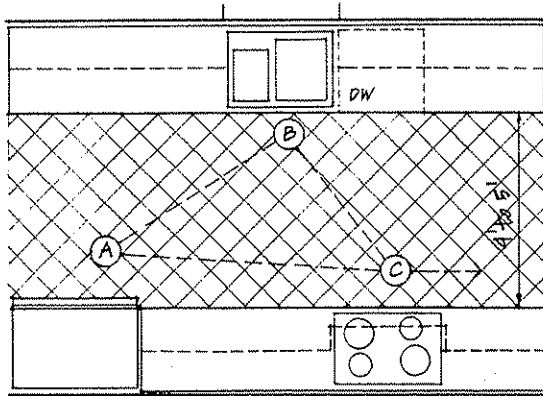
PREFABRICATED FIREPLACES



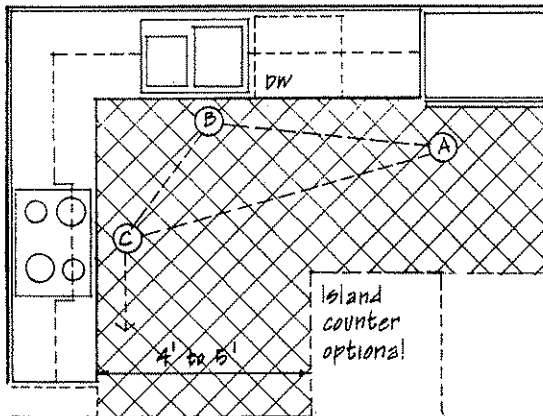
• Consult manufacturer and local codes for installation details and requirements.

WOODBURNING STOVES

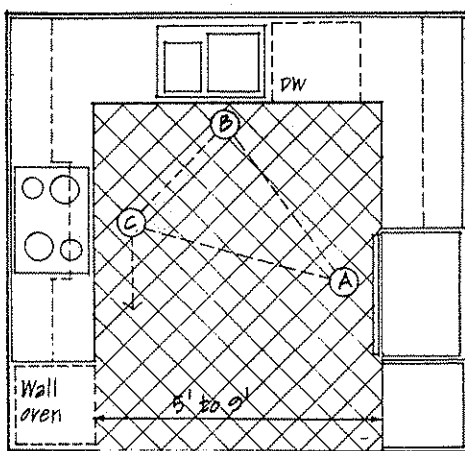
D.18 KITCHEN LAYOUTS



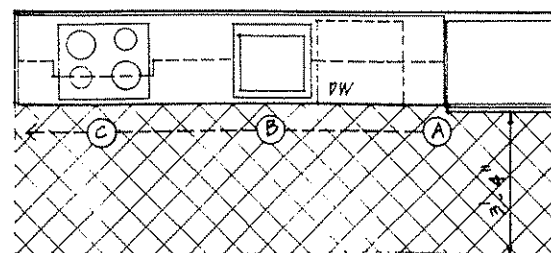
PARALLEL WALL



L-SHAPE



U-SHAPE



SINGLE WALL

These plans illustrate the basic types of kitchen layouts. These plans can be readily adapted to various structural or spatial situations, but they are all based on a work triangle that connects the three major kitchen centers:

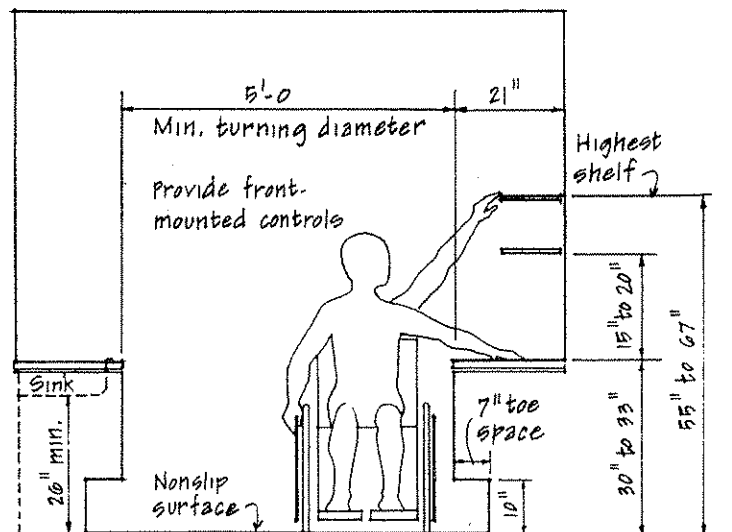
- Ⓐ Refrigerator center for receiving and food preparation;
- Ⓑ Sink center for food preparation and clean-up;
- Ⓒ Range center for cooking and serving.

The sum of the sides of the triangle should not be more than 22' nor less than 12'.

Additional factors to consider in laying out a kitchen space include:

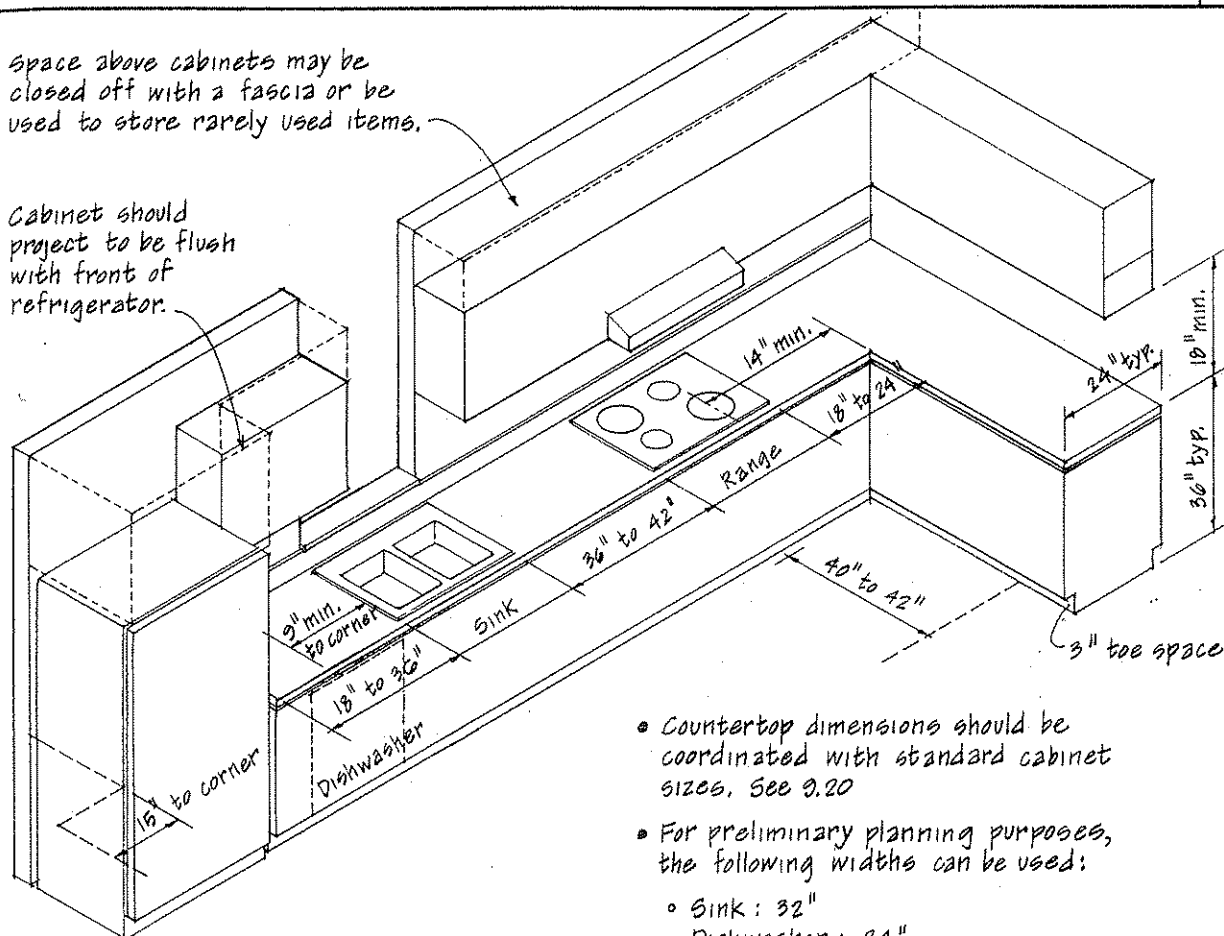
- The type and size of fixtures and appliances to be used
- The amount of work surfaces and storage required
- The degree of enclosure envisioned for the space
- Requirements for natural light, views, and ventilation
- The type and degree of access desired
- The integration of electrical, plumbing, and mechanical systems

HANDICAPPED ACCESS



space above cabinets may be closed off with a fascia or be used to store rarely used items.

Cabinet should project to be flush with front of refrigerator.

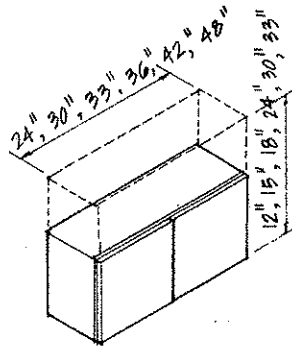


- Countertop dimensions should be coordinated with standard cabinet sizes, See 9.20
- For preliminary planning purposes, the following widths can be used:
 - Sink : 32"
 - Dishwasher : 24"
 - Range : 33"
 - Refrigerator : 32"
- Under counter and overhead storage requirements will influence the layout and work center dimensions.

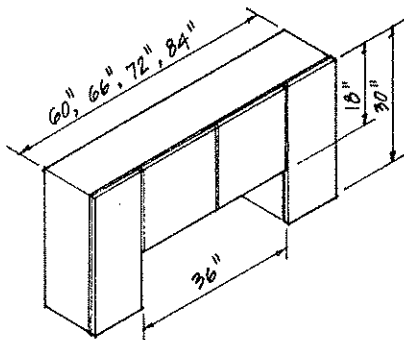
Figure 1 illustrates the clearances and dimensions for kitchen work areas, showing four human figures in various positions relative to the counter and appliances.

- Seated Figure (Left):**
 - Counter height: 24" to 30"
 - Clearance above counter: 18" to 24"
 - Clearance below counter: 36" to 42"
- Standing Figure (Second from Left):**
 - Counter height: 24" to 30"
 - Clearance above counter: 2'-6"
- Standing Figure (Third from Left, at Range):**
 - Range height: 24" min.
 - Clearance above range: 3'-4"
 - Clearance below range: 3" toe space, 3" to 6"
- Standing Figure (Right, at Sink):**
 - Sink height: 24" min.
 - Clearance above sink: 4'-0" to 5'-4"
 - Clearance below sink: 36" typ., 65" to 75"
 - High shelf clearance: 18" min. from counter top

9.20 KITCHEN CABINETS

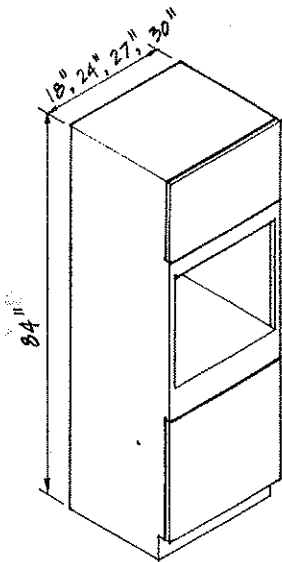


Basic wall unit

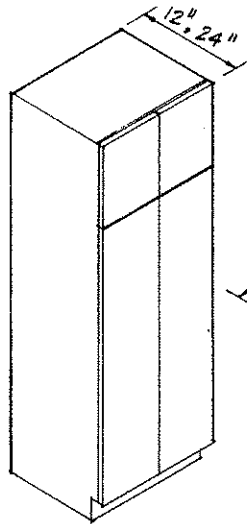
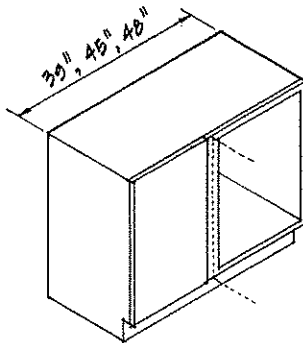
Combination wall unit
for use over sinks and ranges

Kitchen cabinets may be made of enameled steel or of wood. Wood cabinets are usually of particle board or plywood with hardwood frames, and may have plastic laminate, hardwood veneer, or lacquer finishes.

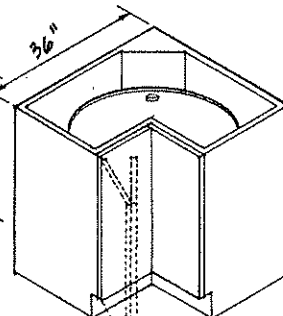
Stock kitchen cabinets are manufactured in 3" modules and should conform to standards established by the National Kitchen Cabinet Association (NKCA). There are three basic types of units: base units, wall units, and special units. Consult manufacturer for available sizes, finishes, hardware, and accessories.



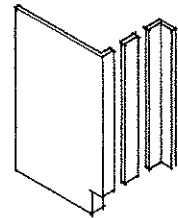
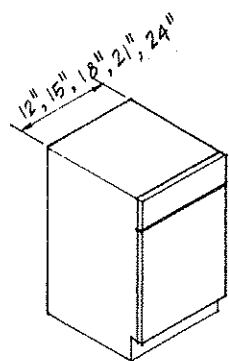
Wall oven unit

Utility closet
or pantry unit

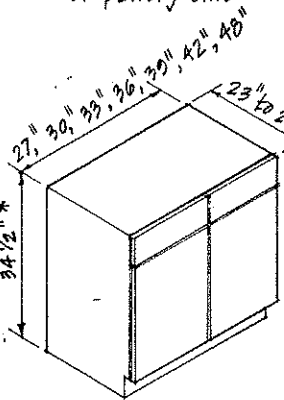
Base corner unit



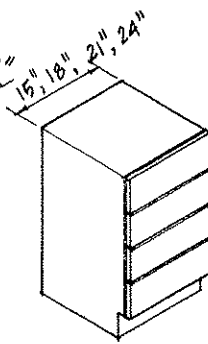
Base corner unit

Finished end
and filler panels

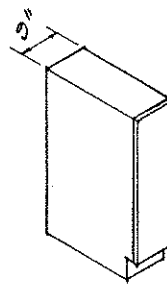
Base unit



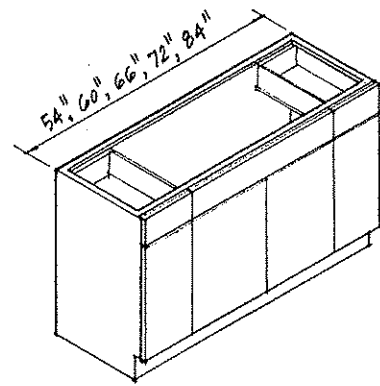
Base unit



Drawer unit



Tray unit



Sink base unit

* 34 1/2" height allows for countertop up to 1 1/2" thick.

- Base units for bathroom vanities are 30" high and 21" deep.
- Base units for buffets and desks are 28 1/2" high.

THE KITCHEN SPACE

D.21

• VENTILATION

Range center may be ventilated by a hood with an exhaust fan

- Vertically through roof
- Directly through exterior wall
- Horizontally to outside through soffit above wall cabinets.

Self-venting cooktops may exhaust directly to outside or, if in an interior location, through a duct in the floor system.

• ELECTRICAL

A minimum of two circuits for small appliances should be provided with outlets spaced 4' a.c. and about 6" above the countertop. These circuits should be protected by a ground fault interrupter (GFI).

Special, single outlet circuits are required for permanently installed appliances such as ranges and ovens.

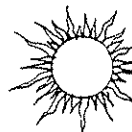
Separate circuits are also required for appliances such as the refrigerator, dishwasher, garbage disposal unit, and microwave oven.

• GAS

Gas appliances require their separate fuel supply lines.

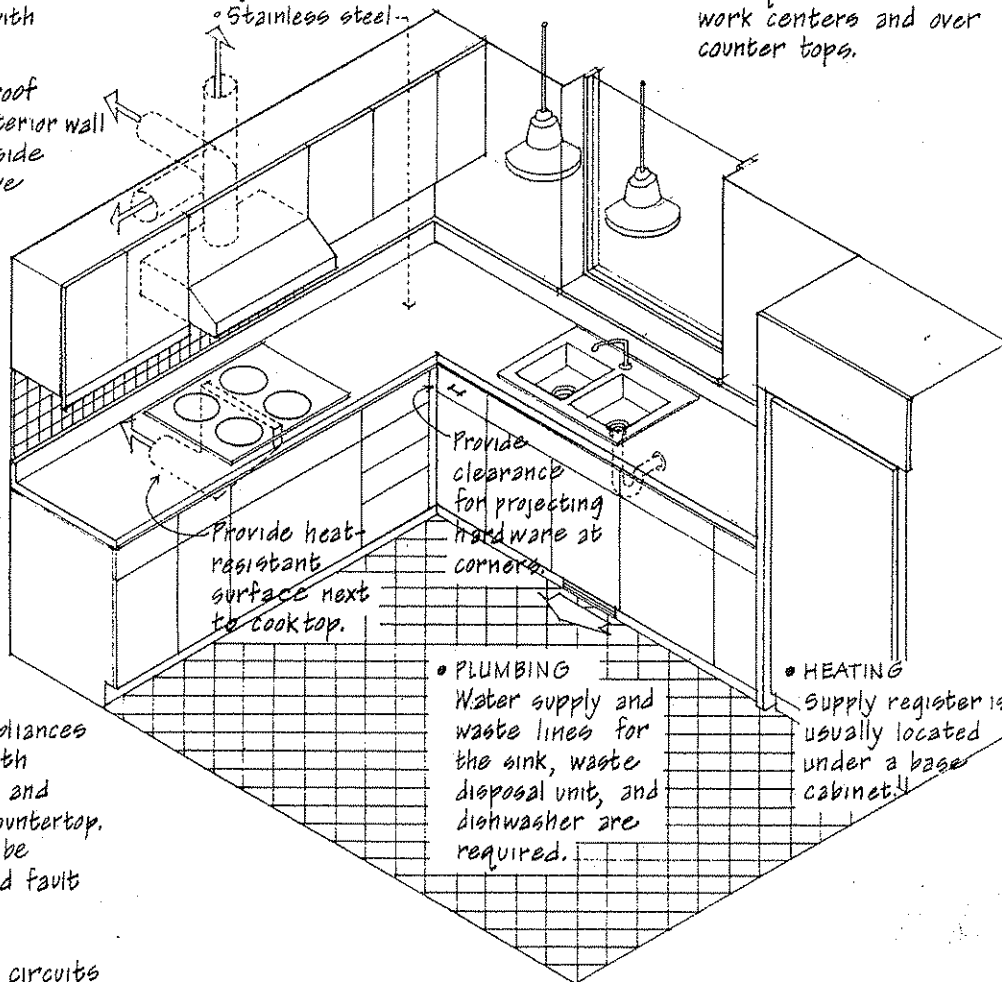
Counter top surfaces :

- Plastic laminate
- Butcher block
- Ceramic tile
- Marble or granite
- Synthetic stone
- Stainless steel



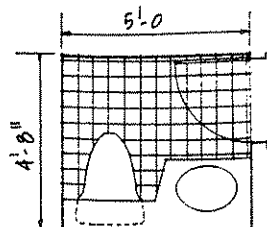
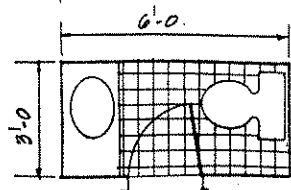
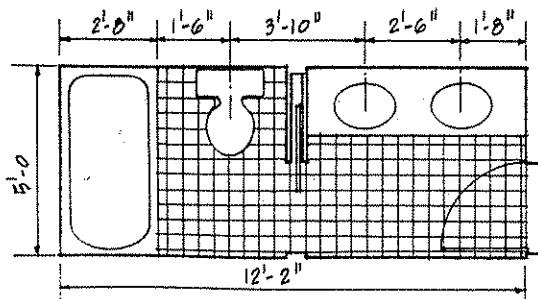
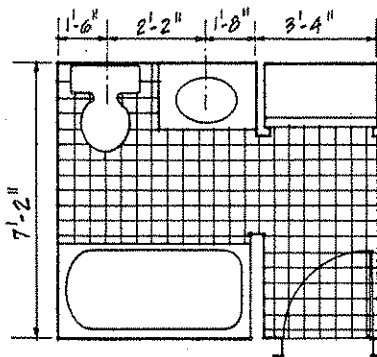
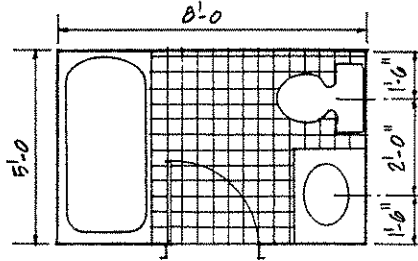
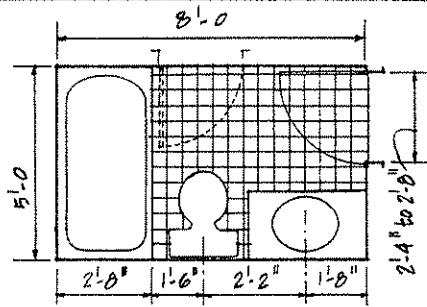
- LIGHTING
Daylighting is always preferred.

In addition to general area lighting, task lighting is required over each of the work centers and over counter tops.



Flooring should be slip-resistant, durable, easy to maintain, and resistant to water and grease.

22 BATHROOM LAYOUTS

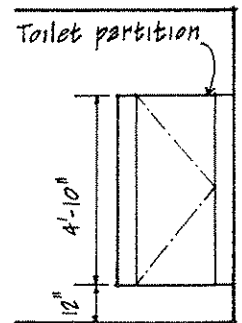
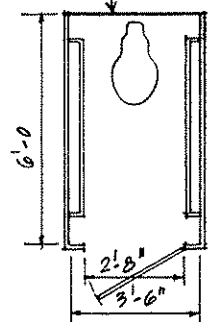
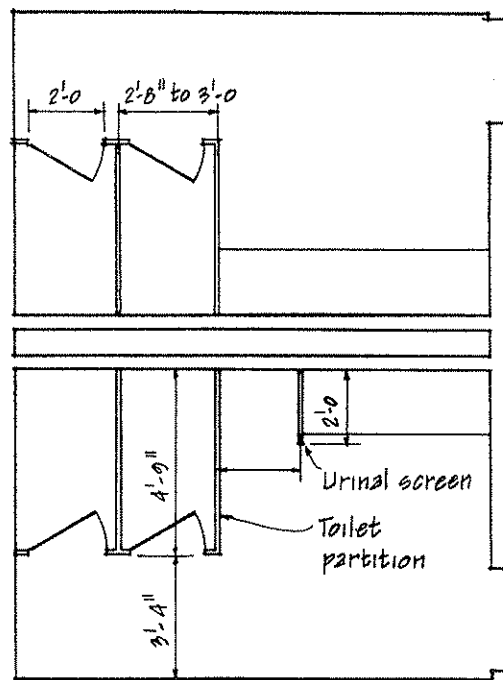
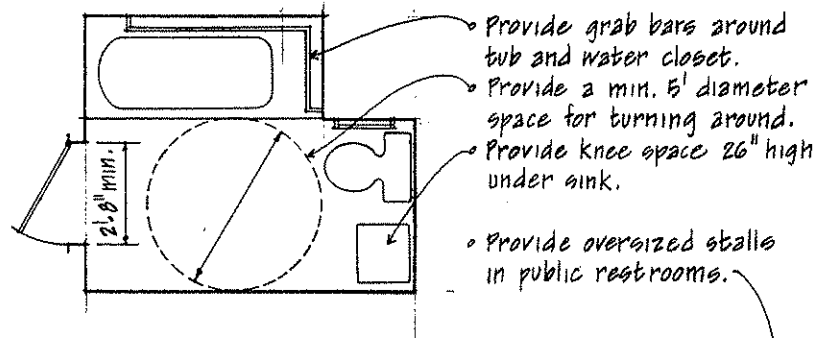


These bathroom plans illustrate basic layouts and relationships which can be adjusted to suit specific situations. Fixture spacing and clearances are important for safe and comfortable movement within a bathroom space. Recommended dimensions can be perceived through the study of these plans and the drawings on the facing page. The overall dimensions of a bathroom may vary according to the actual sizes of the fixtures used.

The layout of bathrooms and other restroom facilities should also take into account:

- the space for and locations of accessories such as towel bars, mirrors, and medicine cabinets
- the number of plumbing walls required and the location of stacks, vents, and horizontal runs.

WHEELCHAIR ACCESS

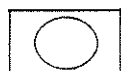


PLUMBING FIXTURES

D.25



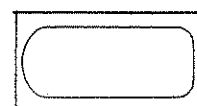
Water closet



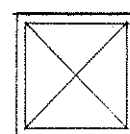
Lavatory



Lavatory



Bathtub



Shower

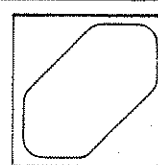
Width:	20" to 24" (seat 14")	30" to 36"	18" to 24"	3'-6" to 6'-0"	2'-6" to 3'-6"
Depth:	22" to 29"	21"	16" to 21"	2'-6" to 2'-8"	2'-6" to 3'-6"
Height:	20" to 28" (seat 15")	31"	31" rim to floor	12" to 20"	6'-2" to 6'-8"



Urinal



Bidet



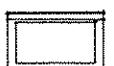
Square bathtub



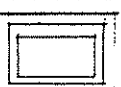
Water cooler

May be surface mounted, semi-recessed, or fully recessed.

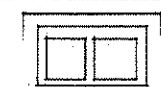
Width:	18"	14"	3'-8" to 4'-2"	10" to 18"
Depth:	12" to 24"	30"	3'-8" to 4'-2"	10" to 14"
Height:	24" rim to floor	14"	12" to 16"	15" to 30"



Utility sink



Single bowl sink



Double bowl



Double bowl with drainboards

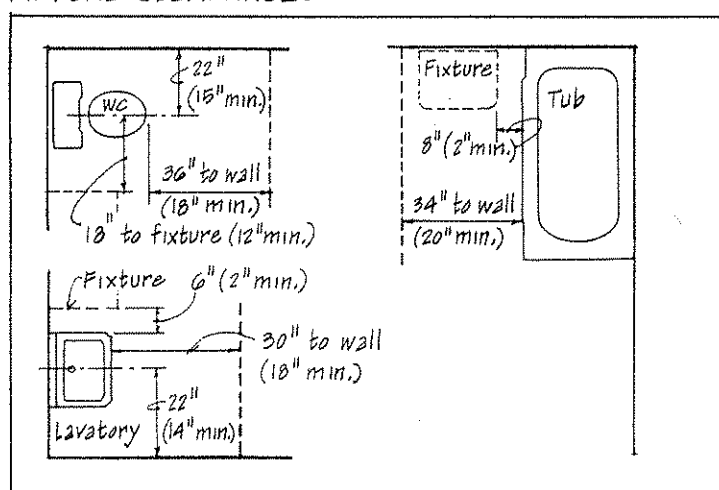
Width:	22" to 48"	12" to 33"	28" to 46"	54" to 84"
Depth:	18" to 22"	13" to 21"	16" to 21"	21" to 25"
Height:	27" to 29" rim to floor	8" to 12"	8" to 10"	8"

The range of fixture dimensions shown above is for preliminary planning. Consult manufacturer for actual dimensions of specific models.

FIXTURE MATERIALS

- Water closets, urinals, and bidets: Vitreous china
- Lavatories, bathtubs, and utility sinks: Vitreous china
Enameled cast iron
Enameled steel
- Shower receptors: Terrazzo
Enameled steel
- Shower enclosures: Enameled steel
Stainless steel
Ceramic tile
Fiberglass
- Kitchen sinks: Enameled cast iron
Enameled steel
Stainless steel

FIXTURE CLEARANCES



24 THE BATHROOM SPACE

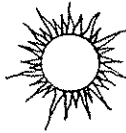
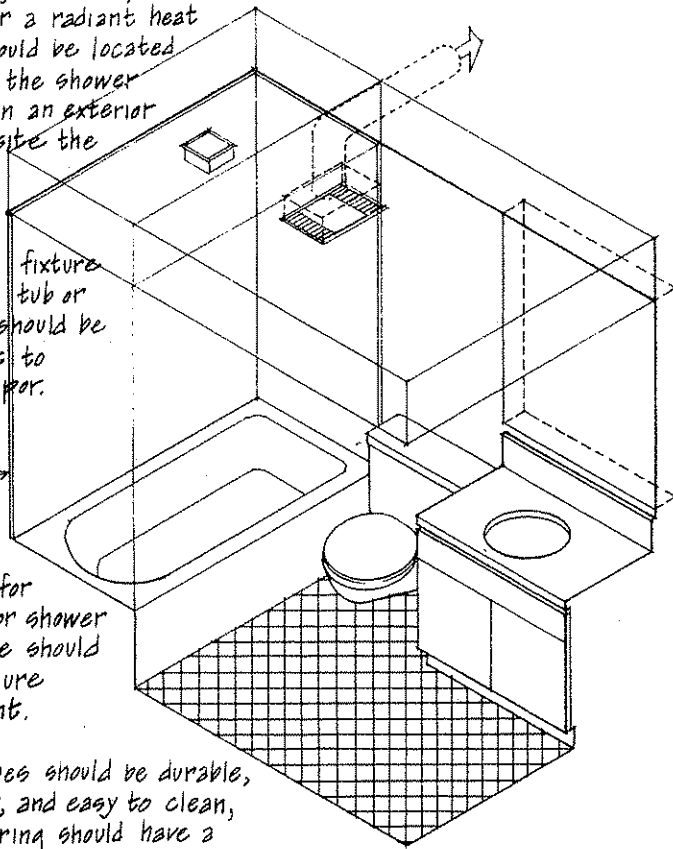
Bathrooms require natural or mechanical ventilation.

- Operable windows or skylights provide natural ventilation.
- Exhaust fan (which may be combined with a light fixture, fan forced heater, or a radiant heat lamp) should be located close to the shower or high on an exterior wall opposite the bathroom door.

- The light fixture over the tub or shower should be resistant to water vapor.

Backing for the tub or shower enclosure should be moisture resistant.

All finishes should be durable, sanitary, and easy to clean, and flooring should have a nonslip surface.



Daylighting is always desirable

A single overhead light fixture is usually not acceptable. Auxiliary lighting is required over the tub or shower, over the lavatory and vanity counter, and over any compartmentalized toilet spaces.

Plumbing walls should have sufficient depth to accommodate the required water supply and waste lines and vents.

Electrical switches and convenience outlets should not be accessible from tub or shower. All convenience outlets should be protected by a ground fault interrupter (GFI).

Space is required for accessories such as a medicine cabinet, mirror, towel bars, toilet paper holder, and soap dish.

Storage space is required for towels, linen, and supplies.

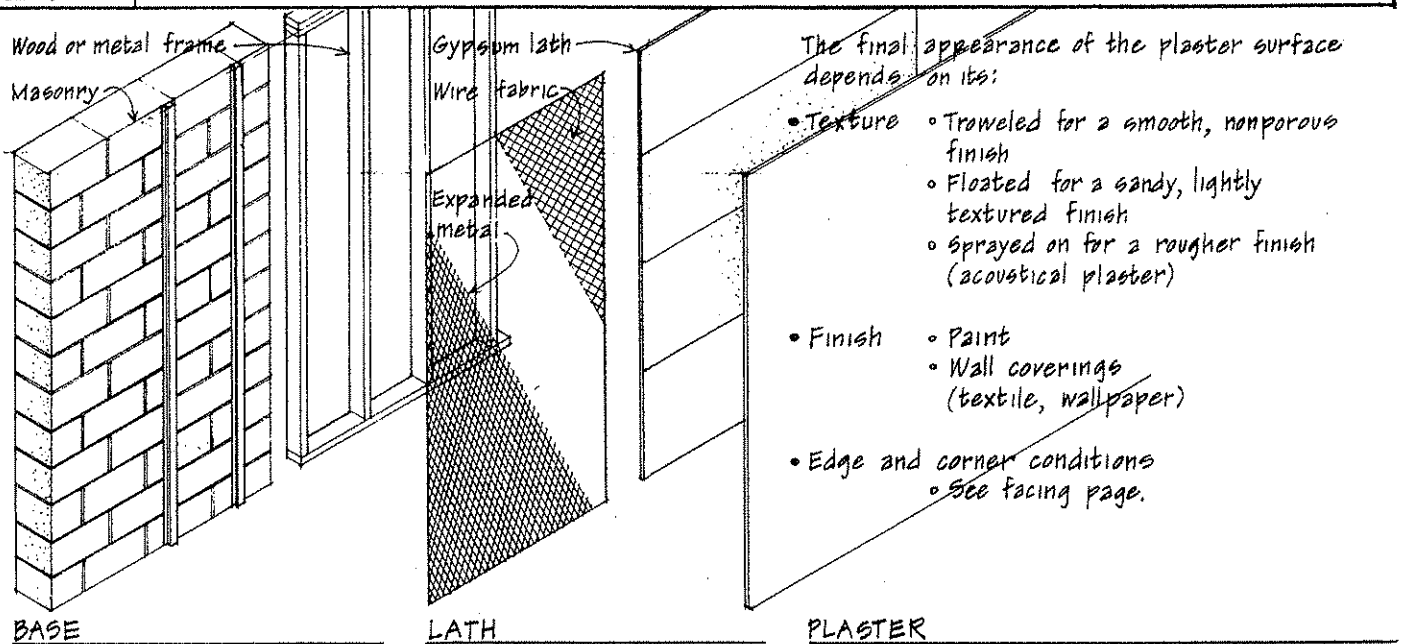
FINISH WORK

This chapter illustrates the major materials and methods used to finish a building's exterior and interior surfaces. Exterior wall surfaces should be durable and weather-resistant. Interior walls should be wear-resistant and cleanable; floors should be durable and safe to walk on; ceilings should be relatively maintenance-free.

Rigid finish materials capable of spanning short distances may be applied to a supporting grid of linear members. More flexible finish materials, on the other hand, require a solid, rigid backing. Additional technical factors to consider include a finish material's acoustic qualities, fire resistance, and thermal insulation value.

Surface finishes have a critical influence on the aesthetic qualities of a space. In the selection and use of a finish material, we should carefully consider color, texture, pattern, and the way it meets and joins with other materials. If a finish material has modular characteristics, then its unit dimensions can be used to regulate the dimensions of a wall, floor, or ceiling surface.

10.2 PLASTER



Masonry Walls:

- Plaster may be applied directly to masonry or concrete surfaces.
- These surfaces must be sufficiently rough and porous to allow for a good bond, and free of oil and other parting materials.
- Bonding agents are used when applying plaster directly to dense, nonporous surfaces such as concrete.
- Where there is a possibility of moisture or condensation getting into the wall, plaster should be applied over lath and furring.

Wood or Metal Framing:

- The framing supports the metal or gypsum lath to which the plaster is applied.
- The frame must be sturdy, rigid, plane, and level.
- Deflection should be limited to 1/360 th of the framing's span.

Metal Lath:

- Metal lath consists of expanded sheet metal or wire fabric.
- The metal is usually a steel alloy which is galvanized or coated with a rust-inhibiting paint.
- The weight and strength of the metal lath used is related to the spacing and rigidity of its supports.
- Paper-backed metal lath is used as a base for ceramic tile and exterior stucco walls.

Gypsum Lath:

- Gypsum lath consists of sheets of hardened gypsum plaster faced with a fibrous paper to which plaster adheres.
- Perforated gypsum lath has 3/4" & holes @ 4" o.c. to improve the plaster bond under fire exposure.
- Insulating (foil-backed) and fire-resistant (Type X) laths are available.

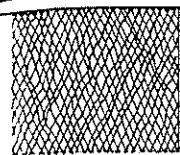
Gypsum Plaster:

Plaster is a cementitious material that sets and hardens to form a finish wall or ceiling surface. Gypsum plaster may be used for any interior wall or ceiling surface that is not subject to severe moisture conditions. Stucco is a portland cement plaster which is used primarily as an exterior cladding material. (See 10.8 for more on stucco.)

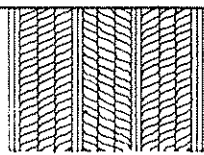
Gypsum plaster consists of calcined gypsum, water, and an aggregate, such as fine sand. Organic fibers may be added to basecoat plaster to help form mechanical keys with metal lath. Wood fiber or perlite is used to decrease the plaster's weight and to increase its fire resistance. Lime is used to improve a plaster's workability. Keene's cement is used in finish coat plasters when a dense, smooth surface is desired.

Plaster is applied in layers, the number of which depends on the type and strength of the base used.

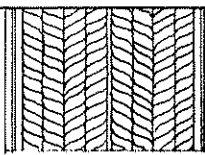
- ① Scratch coat must adhere firmly to the lath and be raked to provide a keyed foundation for the following coats.
- ② Brown coat is brought up to the grade and provides a level base for the finish coat.
- ③ Finish coat is the final thin layer of plaster.



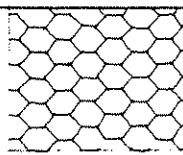
Diamond mesh



1/8" flat rib lath



3/8" rib lath



Woven wire
(for stucco only)

METAL LATHS

Metal lath type	Weight lbs./sq. ft.	Support spacing (inches o.c.)	
		Vertical	Horizontal
Diamond mesh	0.27	16	12
Diamond mesh	0.30	16	16
1/8" flat rib lath	0.31	16	12
1/8" flat rib lath	0.30	24	19
3/8" rib lath	0.38	24	24
Welded or woven wire	0.19	16	16
Wire fabric w/ paper backing	0.19	16	16

3/8" or 1/2" thick

16" wide x 48" long
(24" widths and lengths to 12'
are available.)

GYPSUM LATH

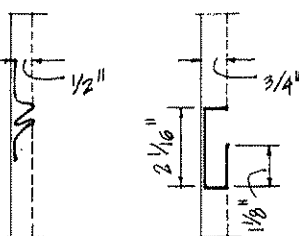
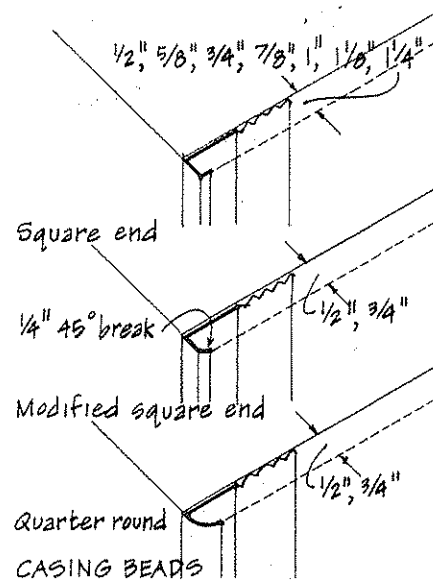
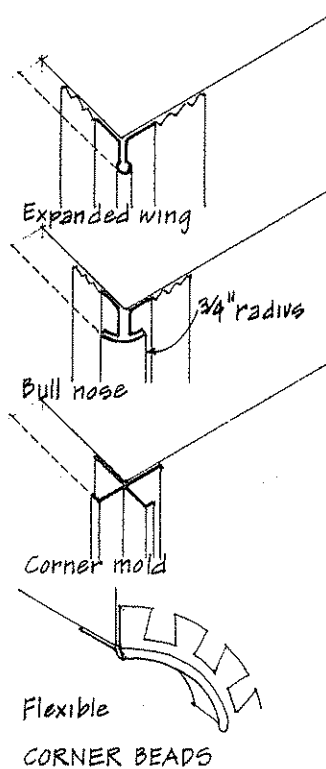
- 16" spacing for both horizontal and vertical applications
- Available with a foil backing which serves as a vapor barrier and a reflective insulator
- Type X lath has glass fibers and other additives to improve its fire resistance.

ACCESSORIES

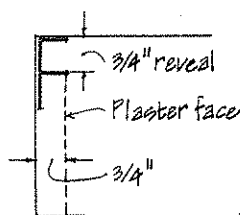
Metal Trim Shapes:

Various metal accessories are used to trim the edges and corners of plaster surfaces. These trim accessories also serve as grounds which help the plasterer level the finish coat and bring it up to the proper thickness. For this reason, all grounds should be securely fastened to their supports and installed straight, level, and plumb.

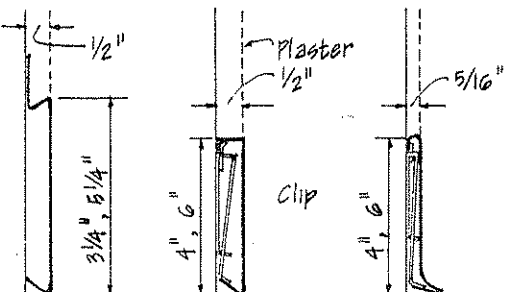
Wood grounds may be used where a nailable base is required for the addition of wood trim.



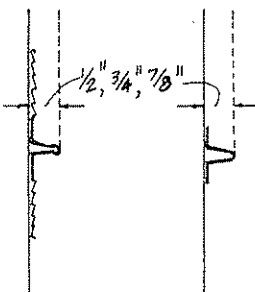
PICTURE MOLDS



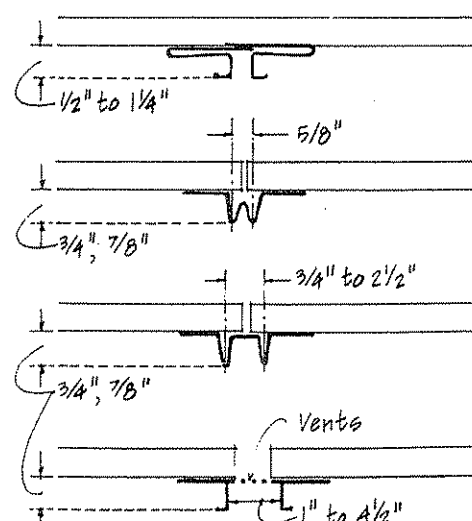
F-REVEAL MOLD



BASES

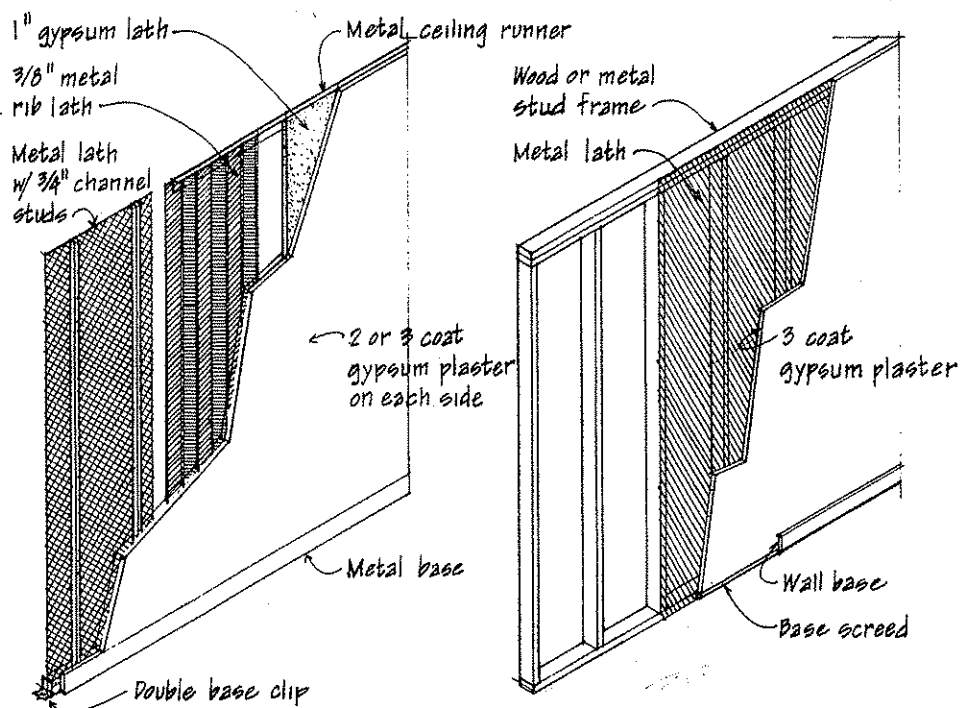


BASE SCREEDS



EXPANSION JOINTS

10.4 PLASTER PARTITION SYSTEMS

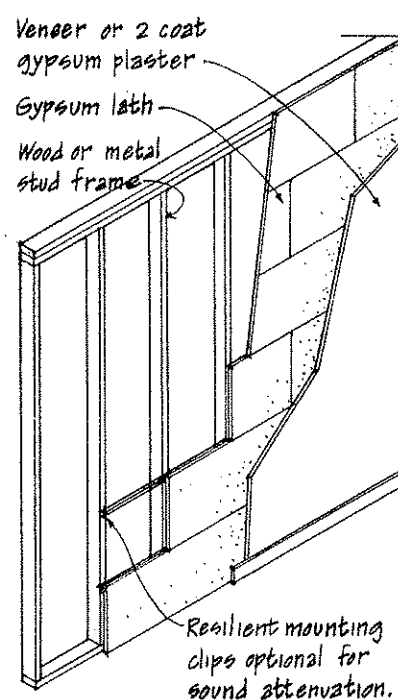


SOLID PLASTER PARTITION

- 2" total thickness of partition conserves floor space.
- 3 coat plaster is applied to both sides of metal or gypsum lath.
- Proprietary ceiling runners and floor runners or base clips are required to stabilize the partition.
- 3/4" channels are used to reinforce the partition around wall openings.

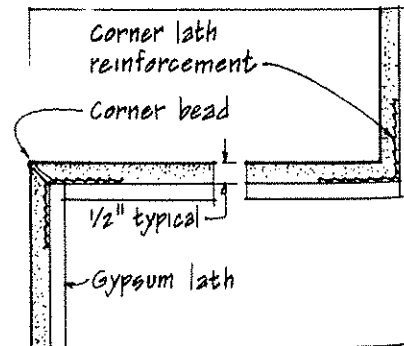
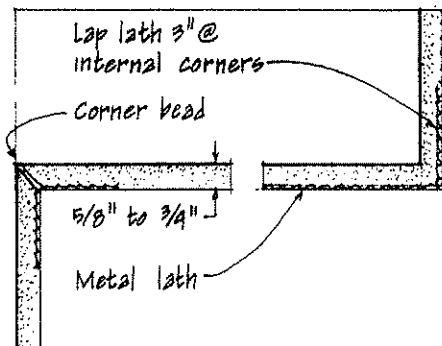
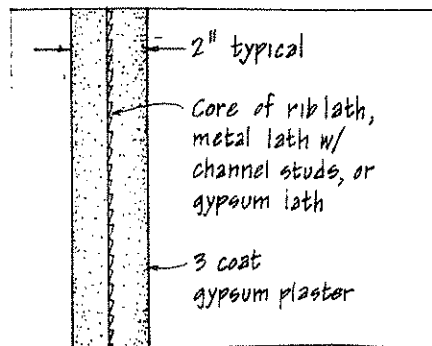
PLASTER OVER METAL LATH

- 3 coat plaster with a total thickness of 5/8" to 3/4" is applied over metal lath.
- The wood or metal studs are spaced 16" or 24" o.c., depending on the weight of metal lath used. See table on 10.3.
- The long dimension of the lath is laid across the supports; rib laid with the ribs across the supports.
- Lath is lapped 1/2" on the sides, 1" at the ends, and 3" at internal corners; use corner beads at external corners.



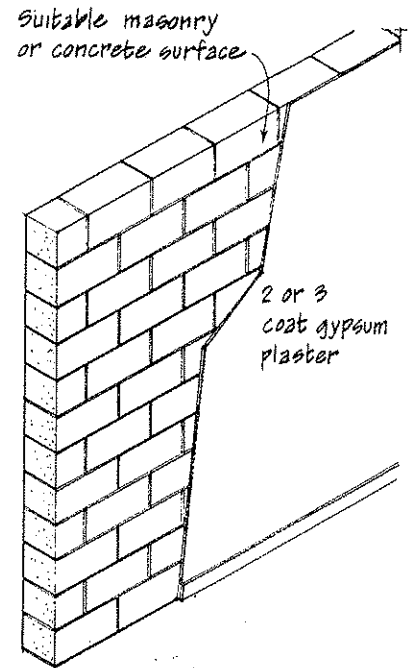
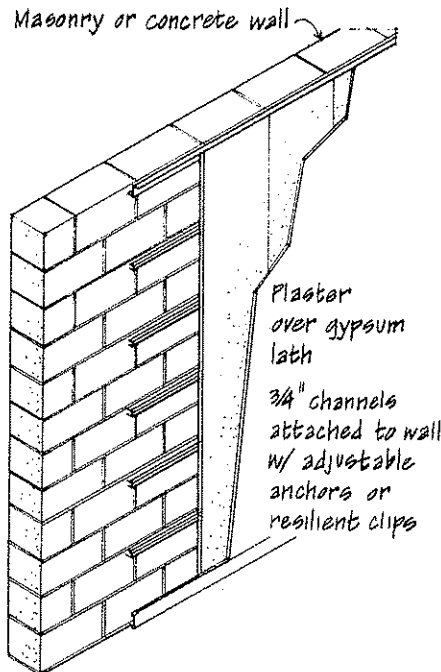
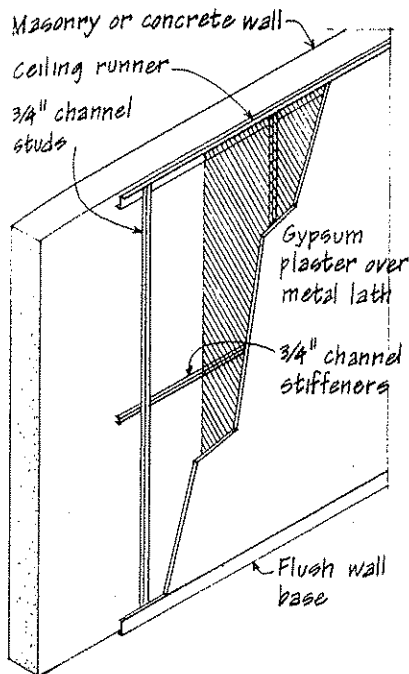
PLASTER OVER GYPSUM LATH

- 2 coat plaster is normally used over gypsum lath.
- Veneer plaster is a high strength plaster that can be applied as a very thin (1/16" to 1/8") 1 or 2 coat finish over a special gypsum board base.
- Supports are spaced 16" o.c. for 3/8" lath, and 24" o.c. for 1/2" lath.
- The long dimension of the lath is laid across the supports; ends of lath should bear on a support or be supported by sheet metal clips.



PLASTER OVER MASONRY WALLS

11.5



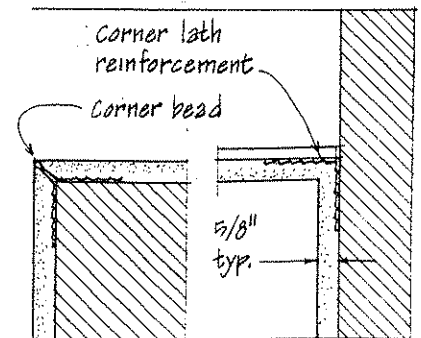
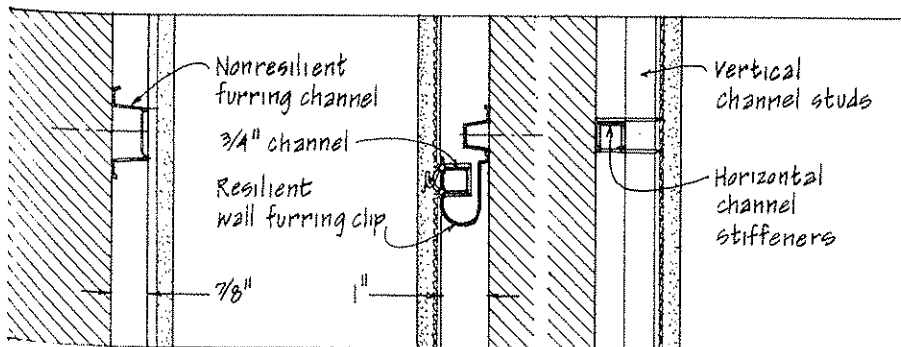
PLASTER OVER FURRING

PLASTER OVER FURRING

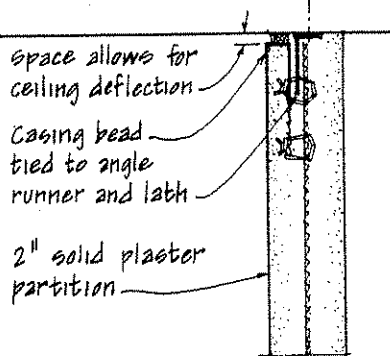
DIRECT APPLICATION

- Plaster should be applied over lath and furring when:
 - The masonry surface is not suitable for direct application.
 - The possibility exists that moisture or condensation might penetrate the wall.
 - Additional air space or space for insulating material is required.
 - A resilient wall surface is desired for acoustical treatment of the space.
- Plaster requires either metal or gypsum lath over the furring; the application and support spacing are similar to the examples shown on the preceding page.
- Wood or metal furring may be applied vertically or horizontally.
- Horizontal stiffeners may be required for vertical furring that is installed away from the wall.
- Furring may be attached to the wall with resilient clips for acoustical treatment and independent movement between the plaster and masonry.
- Wall anchors are available that adjust to various furring depths.

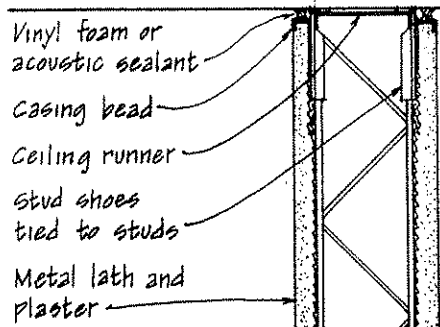
- 2 coat plaster, 5/8" thick, is normally used when applied directly over masonry.
- Plaster may be applied directly to brick, clay tile, or concrete masonry if the surface is sufficiently rough and porous to allow for a good bond.
- A bonding agent is required when applying plaster directly to dense, nonporous surfaces such as concrete.



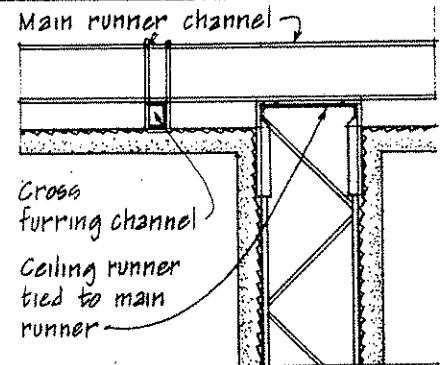
10.6 TYPICAL PLASTER DETAILS



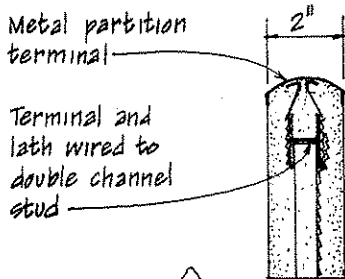
CEILING DETAIL



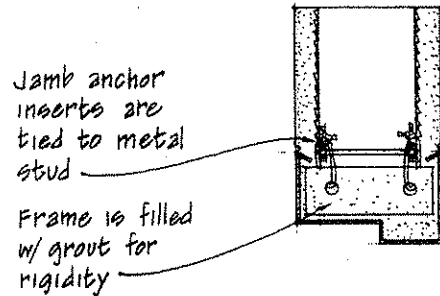
CEILING DETAIL



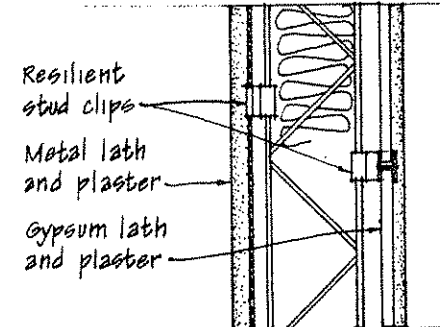
CEILING DETAIL



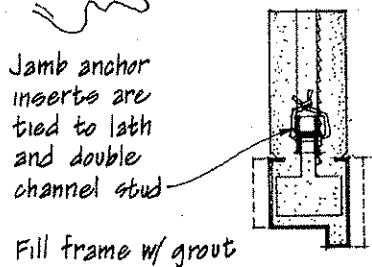
PARTITION END DETAIL



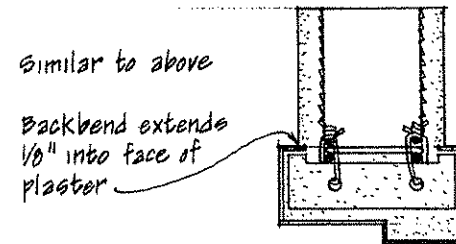
METAL DOOR FRAME (FLUSH)



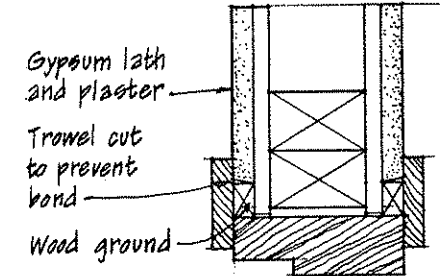
ACOUSTIC WALL TREATMENT



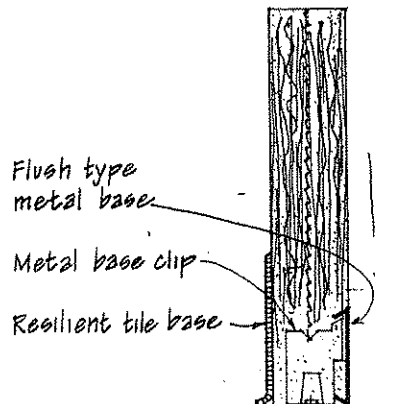
METAL DOOR FRAME



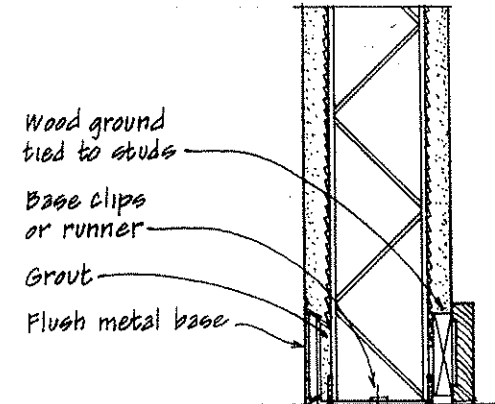
METAL DOOR FRAME (W/ REVEAL)



WOOD DOOR FRAME



ALTERNATIVE BASE DETAILS



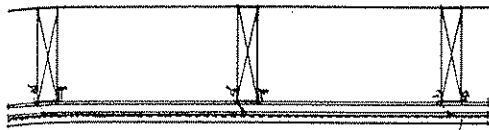
Base screed is used for changes of material

Casing bead

Tile base

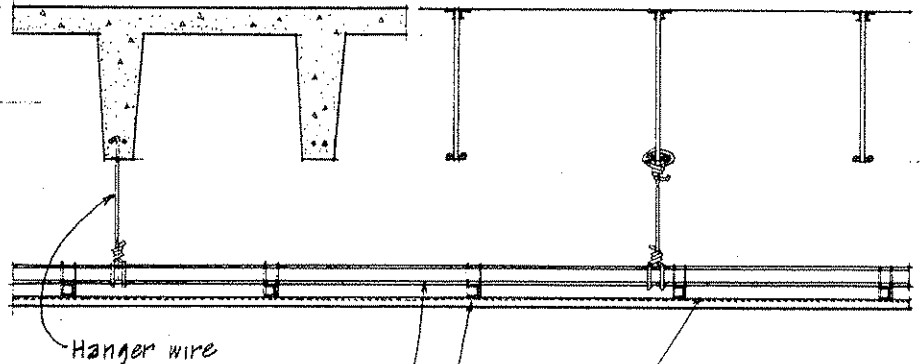
PLASTER CEILINGS

110.7



If lath is nailed directly to the joists, the plaster is subject to cracking due to wood shrinkage. Even when furring is used, deflection of the supporting members should be limited to $1/360$ th of their span.

Suspending the plaster ceiling allows it to move independently of the supporting floor or roof structure, and also provides a concealed space for mechanical and lighting systems.

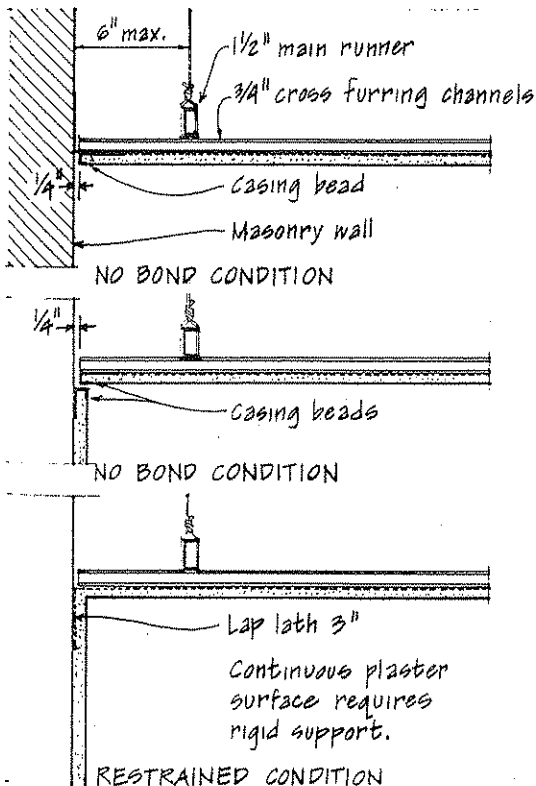


Hanger wire

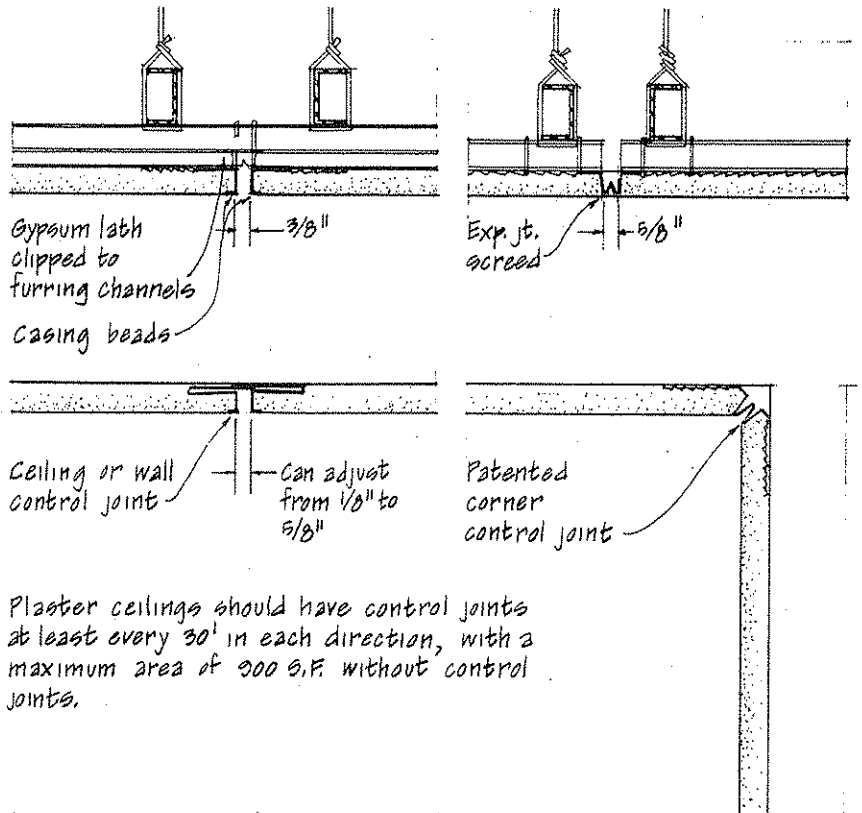
$1\frac{1}{2}$ " main runner channels spaced up to 4'-0" o.c.

$\frac{3}{4}$ " cross furring channels tied to the main runners; see table on 10.3 for spacing.

Metal lath is tied to the furring @ 6" o.c.



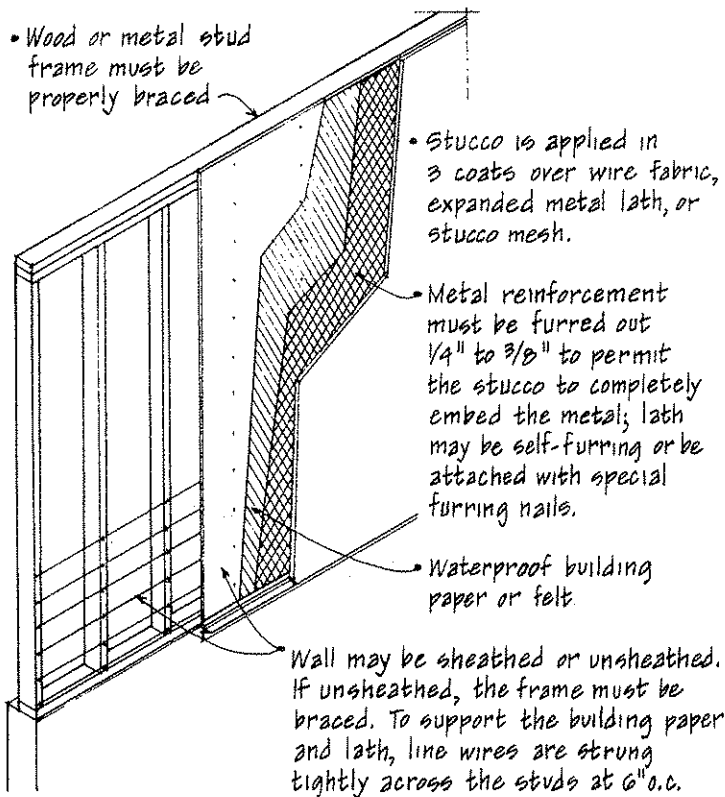
WALL AND CEILING JOINTS



TYPES OF CONTROL JOINTS

Plaster ceilings should have control joints at least every 30' in each direction, with a maximum area of 900 S.F. without control joints.

10.8 STUCCO

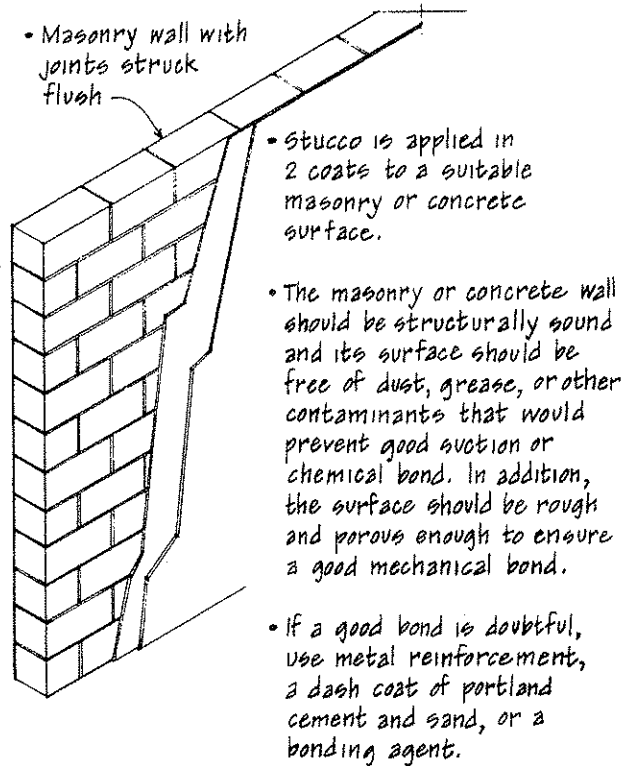


STUCCO OVER FRAME CONSTRUCTION

Thickness of portland cement stucco

Base	Minimum finished thickness from face of base
Expanded metal lath or wire fabric	7/8" (exterior) 5/8" (interior)
Masonry walls	1/2"
Concrete walls	7/8" maximum
Concrete ceilings	3/8" maximum

The finish coat may have a float, stippled, combed, or pebbled texture. The finish may be natural or be integrally colored through the use of pigment, colored sand, or stone chips.



STUCCO OVER MASONRY WALLS

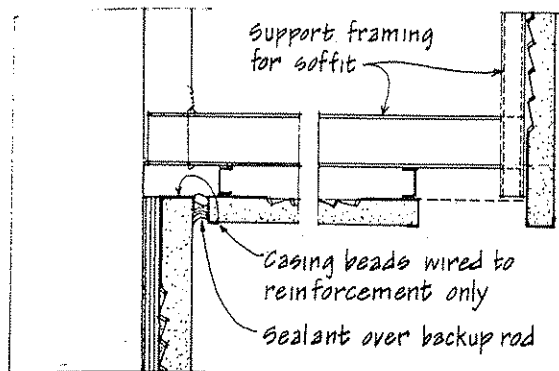
Stucco or exterior plaster is normally used for exterior walls and soffits. It can also be used for interior walls and ceilings that are subject to direct wetting or high moisture conditions.

Stucco is similar to gypsum plaster in its formulation and application, but portland cement is used instead of gypsum to produce a surface that is both weather- and fire-resistant.

Like gypsum plaster, stucco is a relatively thin, hard, brittle material that requires reinforcement or a sturdy, rigid, unyielding base. Unlike gypsum plaster, which expands slightly as it hardens, portland cement stucco shrinks as it cures. This shrinkage, along with the stresses caused by structural movement of the base support and variations in temperature and humidity, can cause the stucco to crack. Control and relief joints are required to eliminate or minimize any cracking.

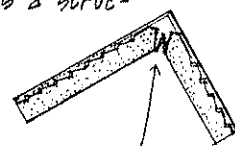
TYPICAL STUCCO DETAILS

10.9

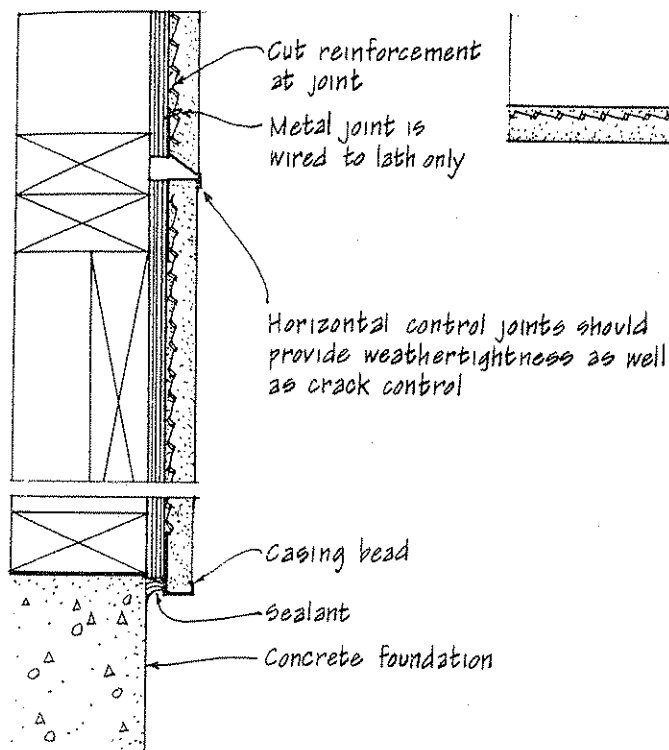


RELIEF JOINT @ SOFFIT

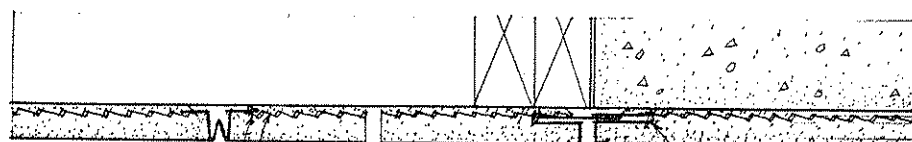
Relief joints permit unrestrained movement of the stucco membrane. They are required at internal corners and where the stucco abuts a structural element.



RELIEF JOINT @ INTERNAL CORNER



BASE DETAIL



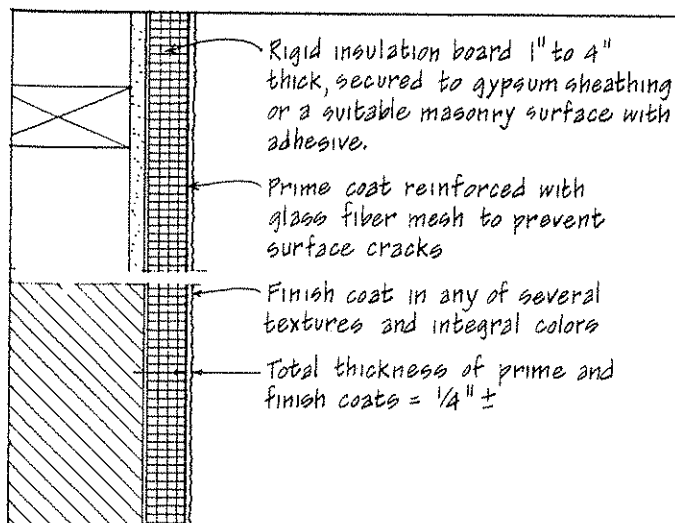
Cut reinforcement at joint
Metal joint is wired to lath only

CONTROL JOINTS

Control joints prealign the cracking that can occur due to volume changes and building movements. When stucco is applied over metal reinforcement, control joints should be spaced 10' apart and define panels no larger than 150 S.F.

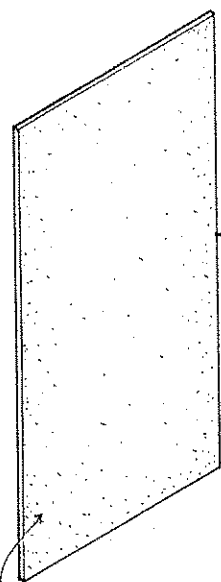
When stucco is applied directly to a masonry base, control joints should be installed directly over and aligned with any control joints existing in the base.

Control joints are also required where dissimilar base materials meet and along floor lines in wood frame construction.

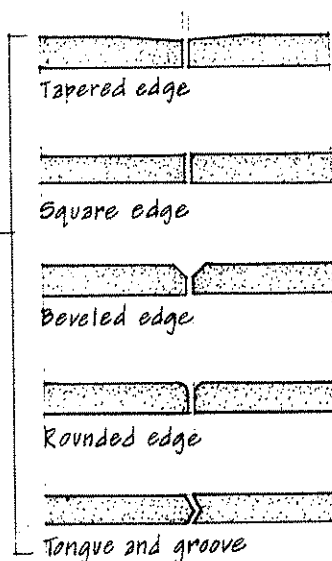


Acrylic-based stucco systems are available for cladding the exteriors of buildings. The system consists of a thin layer of acrylic polymer stucco, reinforced with glass fiber mesh and applied over a layer of rigid plastic foam insulation. The rigid insulation can be secured with adhesive to either masonry or sheathed frame walls. To improve the system's impact resistance, the acrylic stucco can be reinforced with heavy-duty mesh. Consult manufacturer for details.

10.10 GYPSUM BOARD



Paper facing over a gypsum core



TYPES OF EDGES

Gypsum board consists of a gypsum core surfaced and edged to satisfy specific performance, location, application, and appearance requirements. It has good fire resistance and dimensional stability. In addition, its relatively large sheet size makes it an economical material to install. Gypsum wallboard is often referred to as drywall because of its low moisture content and little or no water is used in its application to interior walls or ceilings.

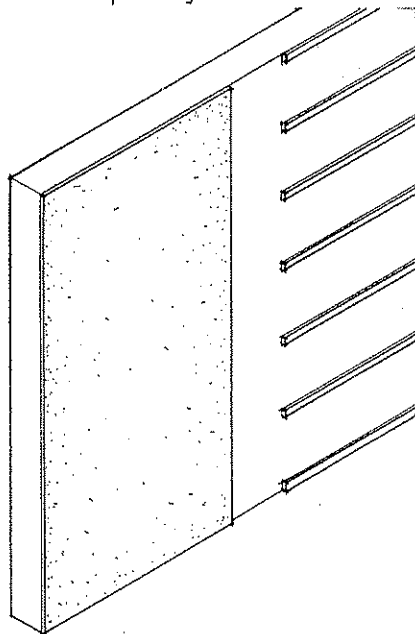
Gypsum board may have different edge conditions. Base or intermediate boards in multilayer construction may have square or tongue-and-groove edges. Prefinished boards may have square or beveled edges. Most commonly, however, gypsum board has a tapered edge. The tapered edge allows the joints to be taped and filled to produce strong, invisible seams. Gypsum board thus can form smooth surfaces which are monolithic in appearance and which can be finished by painting or applying a paper, vinyl, or fabric wall covering.

TYPE AND EDGE	THICKNESS	SIZE	USE OR DESCRIPTION
Regular wallboard Tapered edge	1/4", 3/8", 1/2", 5/8"	4' wide; 8' to 16' long	1/4" board is used as the base layer in sound control walls; 3/8" board is used in multilayer construction, and for remodeling projects; 1/2" and 5/8" boards are for single layer construction.
Coreboard; square or t&g edge	1"	2' wide 4' to 16'	Used to enclose elevator shafts, stairways, and mechanical chases, and for solid gypsum partitions.
Foil-backed board; square or tapered edge	3/8", 1/2", 5/8"	4' wide; 8' to 16' long	Aluminum foil backing serves as a vapor barrier and, if facing a min. 3/4" dead air space, as reflective insulation.
Water-resistant board; Tapered edge	1/2", 5/8"	4' wide; 8' to 12' long	Used as a base for ceramic or other nonabsorbent tile in high moisture areas.
Type X board; Tapered or rounded edge	1/2", 5/8"	4' wide; 8' to 16' long	Core has glass fibers and other additives to increase its fire resistance; available with foil backing.
Prefinished board; square edge	5/16"	4' wide; 8' long	Vinyl or paper surfaced in various colors, patterns, and textures.
Backing board; square or t&g edge	3/8", 1/2", 5/8"	4' wide; 8' long	Used as the base in multilayer systems; available with regular or Type X cores, or with foil backing.
Sheathing square or t&g edge	1/2", 5/8"	2' or 4' wide; 8' to 10' long	Used as sheathing for exterior wood or metal stud walls; available with regular or Type X cores.

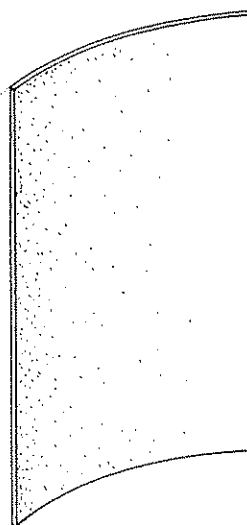
GYPSUM BOARD APPLICATION

11

Gypsum board may be applied to above grade masonry or concrete walls whose surfaces are dry, smooth, plane, and free of oil or other parting materials.

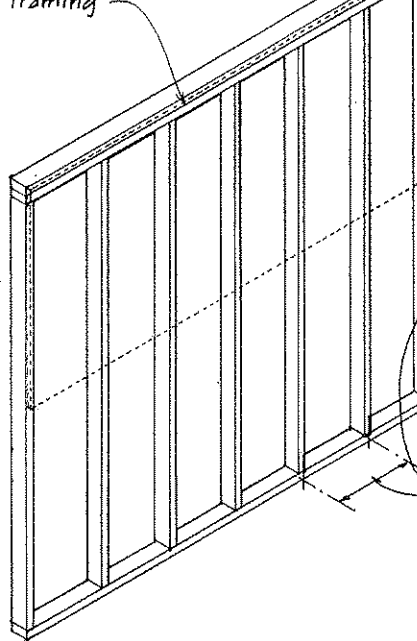


Exterior and below grade masonry or concrete walls require furring before the application of gypsum board to eliminate the capillary transfer of water and to minimize condensation on interior wall surfaces.



Vertical application:
Board length parallel to framing

Horizontal application:
Board length perpendicular to framing



1x2 (min.) wood furring; use 2x2s or metal channels for greater stiffness.

Support spacing:

16" - 3/8" gypsum board min.
(1/2" preferred)

24" - 1/2" gypsum board min.

Wood or metal furring is required when:

- The frame or masonry base is not sufficiently flat.
- The primary supports are spaced too far apart.
- Additional space for thermal or acoustic insulation is desired.
- The use of resilient furring channels is needed to improve the acoustic performance of the assembly.

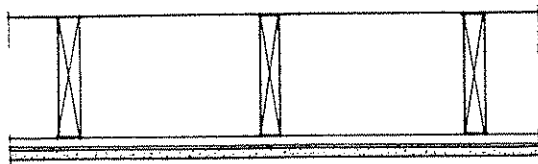
Gypsum board may be fastened directly to wood or metal stud framing that is structurally sound and rigid enough to prevent buckling or cracking of the gypsum board. The face of the frame should form a flat and level plane.

Horizontal application is preferred for greater stiffness if it results in fewer joints. Butt end joints, which should be kept to a minimum, must fall over a support.

Gypsum board can be curved.
The maximum bending radius is as follows.

Board thickness:	Lengthwise:	By width:
1/4"	5'-0"	15'-0"
3/8"	7'-6"	25'-0"
1/2"	20'-0"	

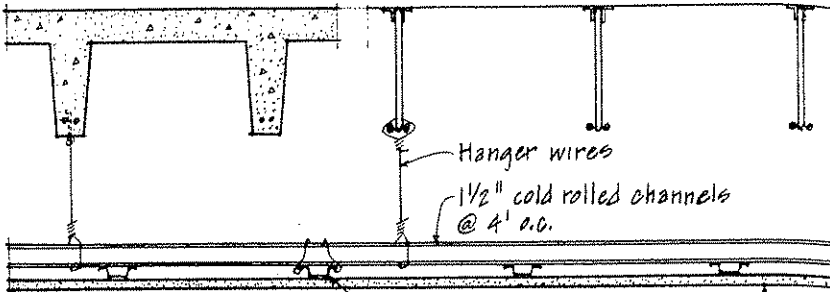
A.12 TYPICAL GYPSUM BOARD DETAILS



Gypsum board may be fastened directly to the bottom of wood joists @ 16" o.c. For fire resistance, Type X board can be used.

For improved resistance to sound transmission, and when attaching the gypsum board to concrete or steel joists, resilient furring channels @ 16" or 24" o.c. are used.

The deflection of the floor or roof structure should be limited to $1/240$ th of its span.



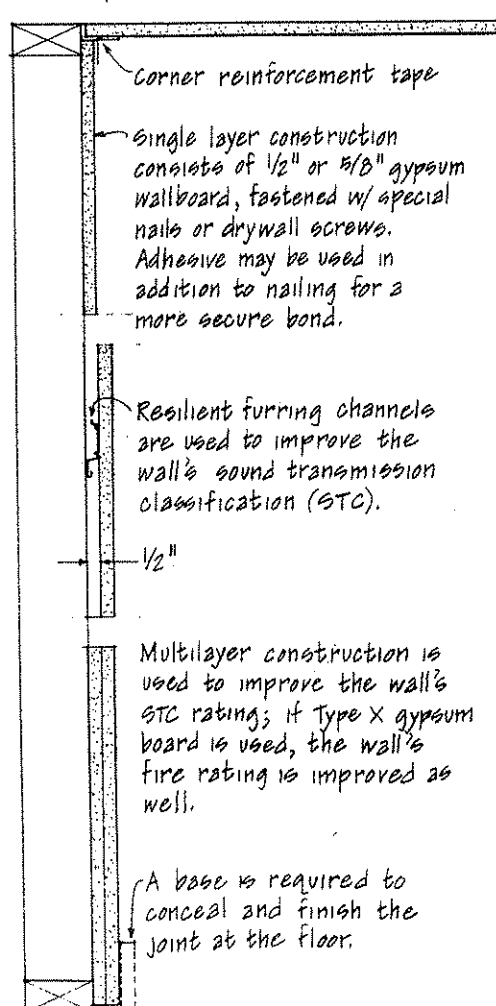
Gypsum board may also be supported by a grid of furring channels and hung as a suspended ceiling.

Hanger wires
1 1/2" cold rolled channels @ 4' o.c.

7/8" metal furring channels @ 16" to 24" o.c., clipped or tied to main channels

1/2" or 5/8" Type X gypsum board

Provide space for structural movement if required.



Corner reinforcement tape

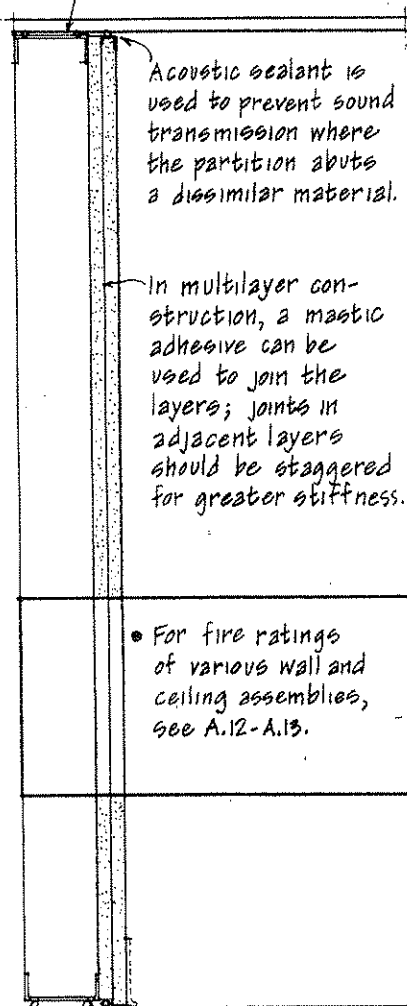
Single layer construction consists of 1/2" or 5/8" gypsum wallboard, fastened w/ special nails or drywall screws. Adhesive may be used in addition to nailing for a more secure bond.

Resilient furring channels are used to improve the wall's sound transmission classification (STC).

1/2"

Multilayer construction is used to improve the wall's STC rating; if Type X gypsum board is used, the wall's fire rating is improved as well.

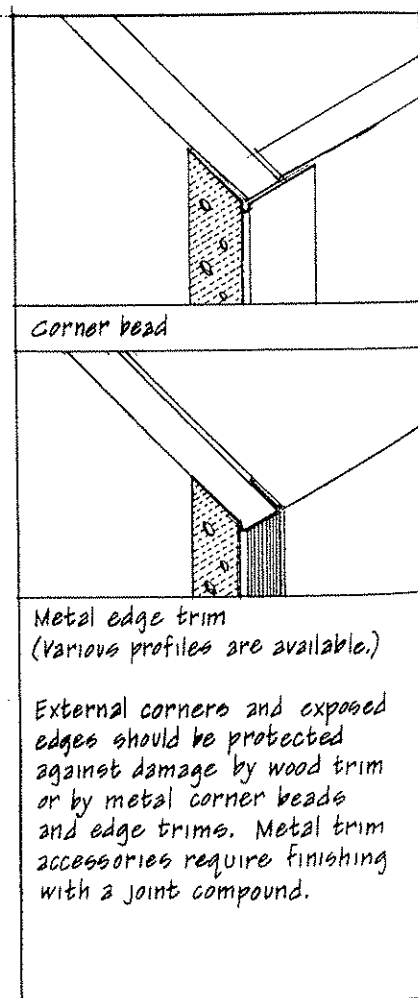
A base is required to conceal and finish the joint at the floor.



Acoustic sealant is used to prevent sound transmission where the partition abuts a dissimilar material.

In multilayer construction, a mastic adhesive can be used to join the layers; joints in adjacent layers should be staggered for greater stiffness.

- For fire ratings of various wall and ceiling assemblies, see A.12-A.13.



Corner bead

Metal edge trim (Various profiles are available.)

External corners and exposed edges should be protected against damage by wood trim or by metal corner beads and edge trims. Metal trim accessories require finishing with a joint compound.

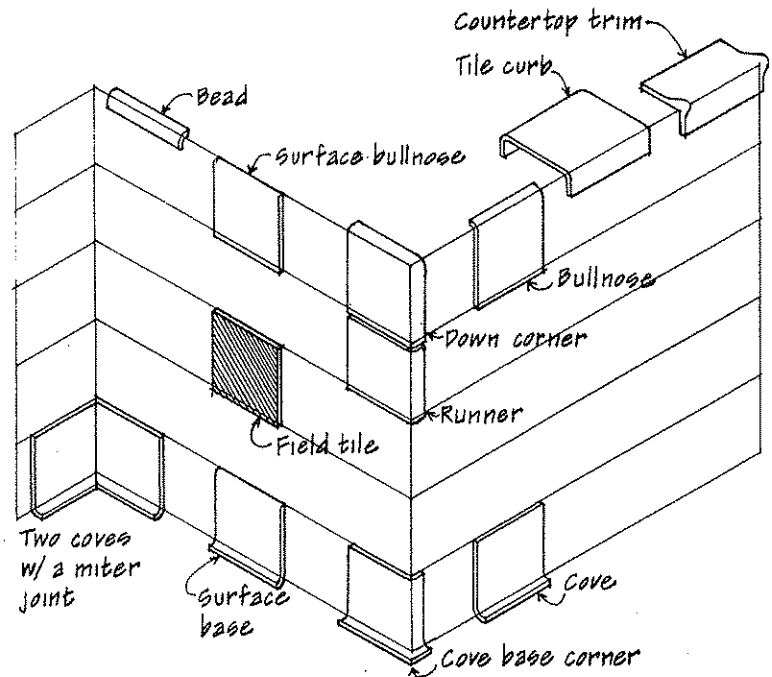
CERAMIC TILE

10.13

Ceramic tiles are relatively small, modular surfacing units made of clay or other ceramic material. The tiles are fired in a kiln at very high temperatures. The result is a durable, tough, dense material that is water-resistant, difficult to stain, and easy to clean, and its colors generally do not fade.

Ceramic tile is available glazed or unglazed. Glazed tile has a face of ceramic material fused into the body of the tile, and may have glossy, matte, or crystalline finishes in a wide range of colors. Unglazed tiles are hard and dense, and derive their color from the body of the material. These colors tend to be more muted.

Ceramic tile may be applied as individual pieces or in sheet form. Ceramic mosaic tiles may be faced with paper or backed with mesh to form 1'x1' or 1'x2' sections with the proper tile spacing. Both glazed wall and ceramic mosaic tiles are also available in large sheets pregrouted with flexible, silicone grout.



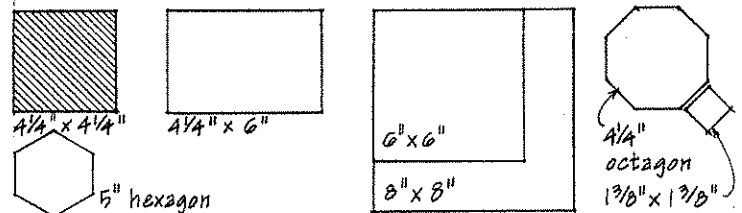
TYPES OF TILE TRIM SHAPES

TYPES AND TYPICAL SIZES OF CERAMIC TILE

Consult manufacturer for exact sizes, shapes, colors, and glazes.

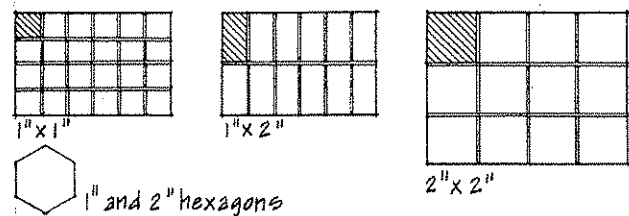
GLAZED WALL TILE (5/16" thick)

Interior tiles are used for interior walls. Exterior tiles are weatherproof and frostproof, and can be used for both exterior and interior walls. With a crystalline glaze, they can be used for light duty floors.



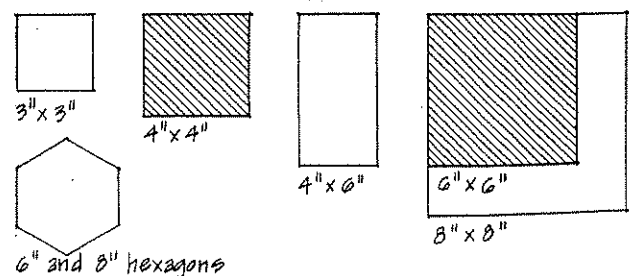
CERAMIC MOSAIC TILE (1/4" thick)

Ceramic mosaic tile is usually unglazed. The porcelain type is resistant to freezing and abrasion, and may be used for floors and walls. Porcelain tiles have bright colors, while the natural clay tiles have more muted colors.



QUARRY AND PAVER TILES (3/8", 1/2", 3/4" thick)

Quarry tile is unglazed floor tile of natural clay or porcelain. The tiles are impervious to dirt, moisture and stains, and resistant to freezing and abrasion. Pavers are similar to ceramic mosaic tiles but larger. They are weatherproof and can be used on floors subject to heavy duty use.

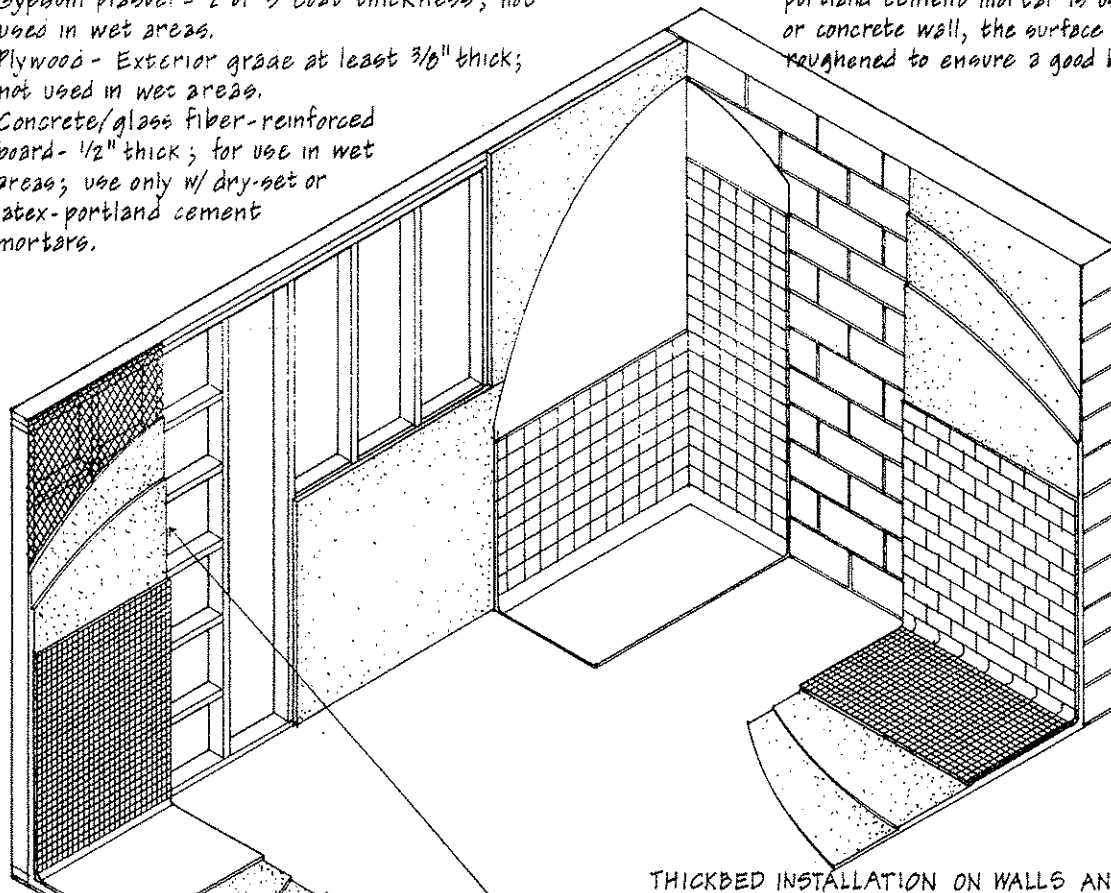


10.14 CERAMIC TILE APPLICATION

THINSET APPLICATION ON WALLS with dry-set mortar, latex-portland cement mortar, or organic adhesive over a solid backing of:

- Gypsum board - Use water-resistant backer board in tub and shower areas.
- Gypsum plaster - 2 or 3 coat thickness; not used in wet areas.
- Plywood - Exterior grade at least $\frac{3}{8}$ " thick; not used in wet areas.
- Concrete/glass fiber-reinforced board - $\frac{1}{2}$ " thick; for use in wet areas; use only w/ dry-set or latex-portland cement mortars.

Wall surfaces should be structurally sound, plumb, and true. When dry-set or latex-portland cement mortar is used on a masonry or concrete wall, the surface should be roughened to ensure a good bond.



THICKBED INSTALLATION ON WALLS AND FLOORS

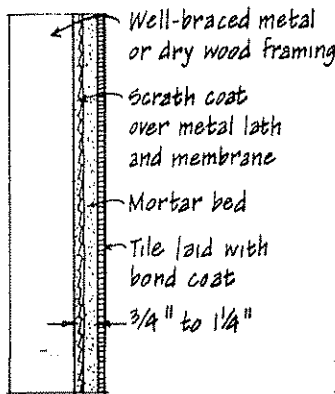
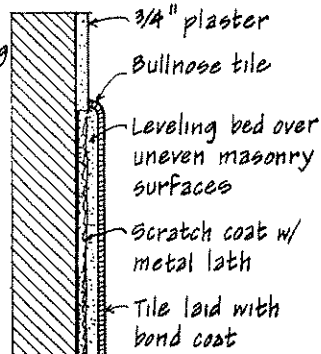
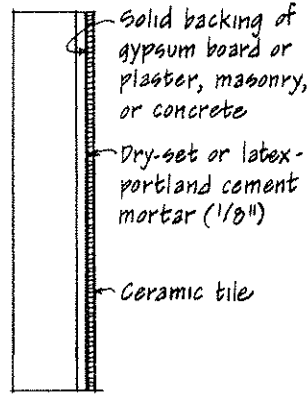
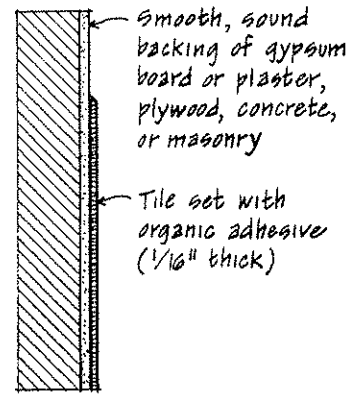
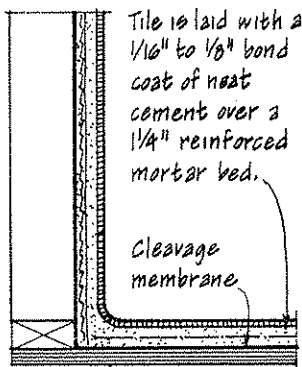
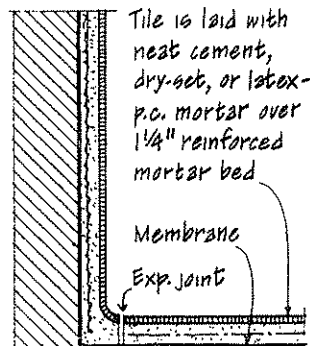
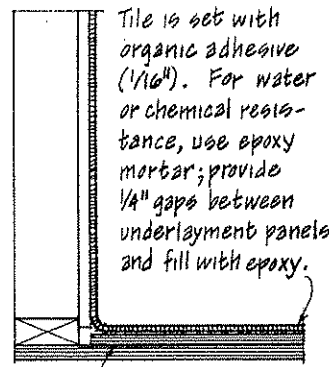
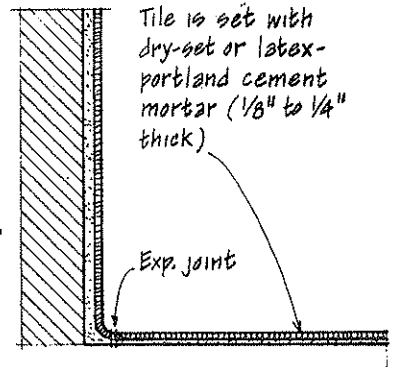
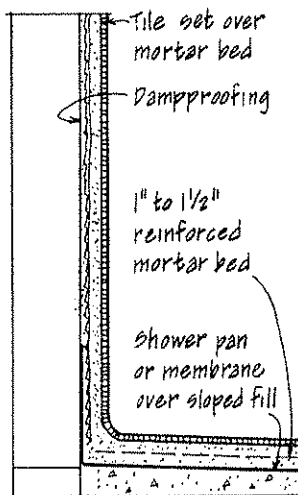
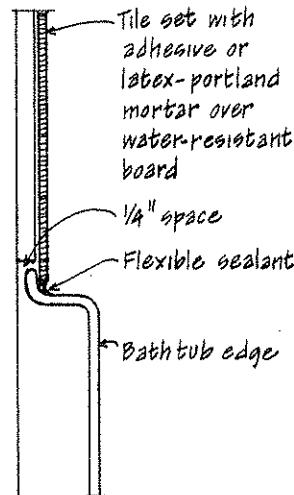
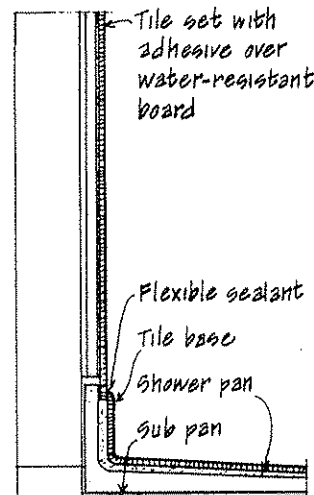
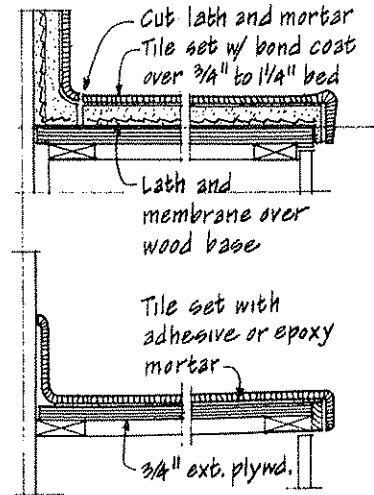
- A relatively thick ($\frac{3}{4}$ " to 1" on walls and $\frac{3}{4}$ " to $1\frac{1}{4}$ " on floors) portland cement mortar bed is used as a setting or leveling bed.
- Tiles are laid with a bond coat of neat portland cement, latex-portland cement, or dry-set mortar.
- A cleavage membrane is used to isolate the mortar bed from damaged or unstable backings and to allow some independent movement of the supporting construction.
- The mortar bed should be reinforced with metal lath or mesh whenever it is backed by a membrane.
- Mortar bed installations can be used over open framing or a solid backing of masonry, concrete, gypsum board or plaster, plywood, or concrete/glass fiber-reinforced backer board.

THINSET APPLICATION ON FLOORS:

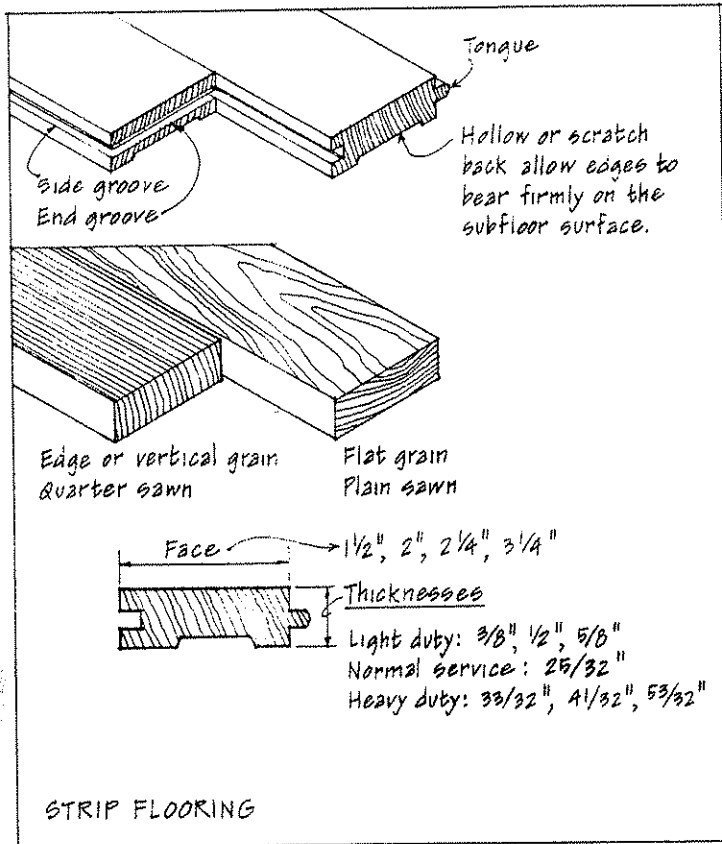
- Maximum deflection of the floor under full load should be limited to $\frac{1}{360}$ th of the span.
- The concrete slab should be smooth, level, and properly reinforced and cured; a leveling topping can be used if required.
- A double wood floor is required, consisting of a $\frac{5}{8}$ " min. plywood subfloor and an underlayment of $\frac{1}{2}$ " or $\frac{5}{8}$ " exterior-grade plywood. A $\frac{1}{4}$ " space should be provided between the underlayment and vertical surfaces.

CERAMIC TILE DETAILS

10.15

Mortar Bed MethodMortar Bed MethodThinset MortarOrganic AdhesiveINTERIOR WALL APPLICATIONSMortar Bed MethodMortar Bed MethodOrganic AdhesiveThinset MortarINTERIOR FLOOR APPLICATIONSCERAMIC TILE SHOWERSTILE TUB ENCLOSURETILE COUNTERTOPS

10.16 WOOD FLOORING

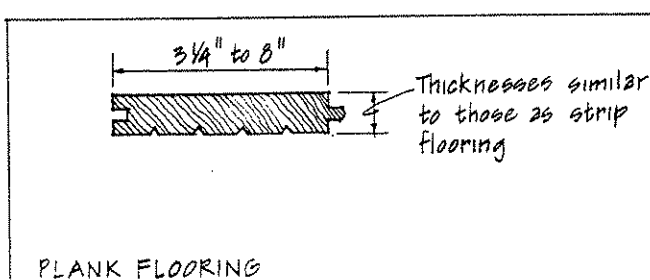


Wood flooring combines durability and wear resistance with comfort and warmth. Durable, hard, close-grained species of both softwood and hardwood are used for flooring. Common species of softwood flooring include southern pine, Douglas fir, hemlock, and other eastern and western pines. Hardwood flooring species include oak, maple, birch, and pecan.

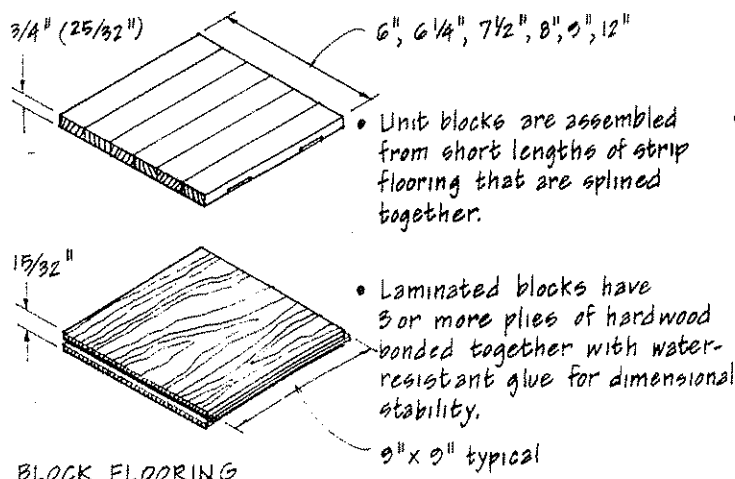
The various species of wood flooring are appearance-graded, but not according to the same standards. The best grades - clear or select - typically minimize or exclude defects such as knots, streaks, checks, and torn grain. Consult the flooring manufacturer or one of the following organizations for precise standards and specifications:

- NOFMA - National Oak Flooring Manufacturers' Association
- MFMA - Maple Flooring Manufacturers' Assoc.
- SPIB - Southern Pine Inspection Bureau
- WWPA - Western Wood Products Association
- NHPMA - Northern Hardwood & Pine Manufacturers' Association

Wood flooring is available in strips, planks, or manufactured blocks and panels.

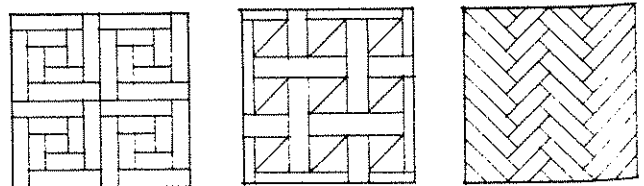


Plank flooring refers to flooring boards that are wider than 3 1/4\". End- and side-matched boards are blind-nailed. The boards may also be face-nailed or screwed and then plugged. Some new plank flooring systems can be laid with mastic or adhesive. To minimize the effect of variations in humidity on the wide planks, 3-ply laminated planks are available.



Block flooring consists of factory-assembled tiles that are usually laid with a mastic.

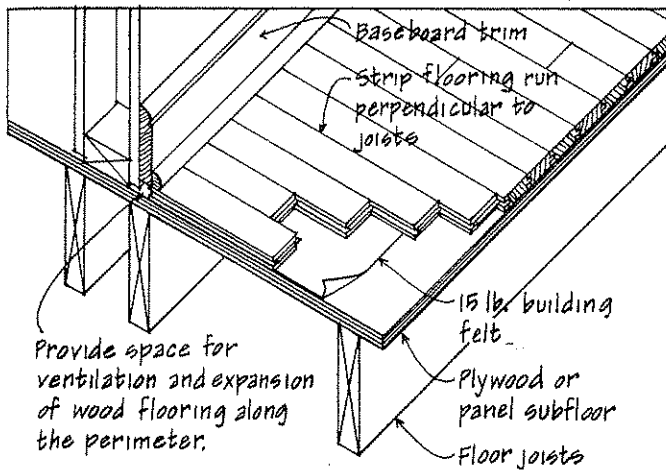
- Unit blocks are assembled from short lengths of strip flooring that are splined together.
- Laminated blocks have 3 or more plies of hardwood bonded together with water-resistant glue for dimensional stability.
- Slat blocks consist of square-edged slats assembled into various parquet patterns. These blocks may be square-edged or grooved and splined, finished or unfinished.



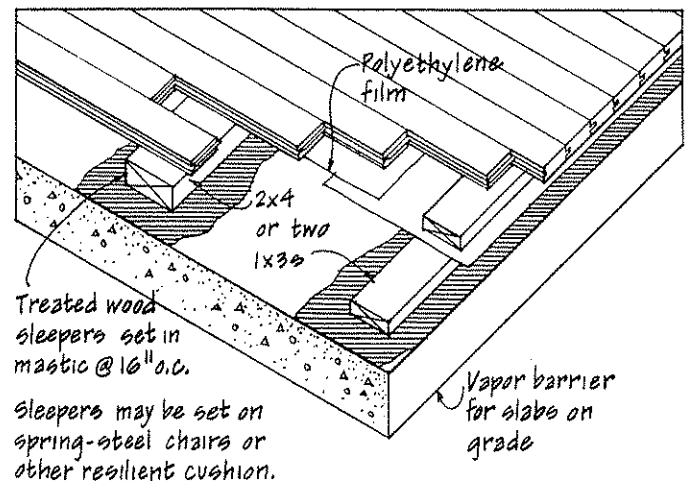
5/16\" thick; 6\"x6\", 12\"x12\", 18\"x18\" typical

WOOD FLOORING INSTALLATION

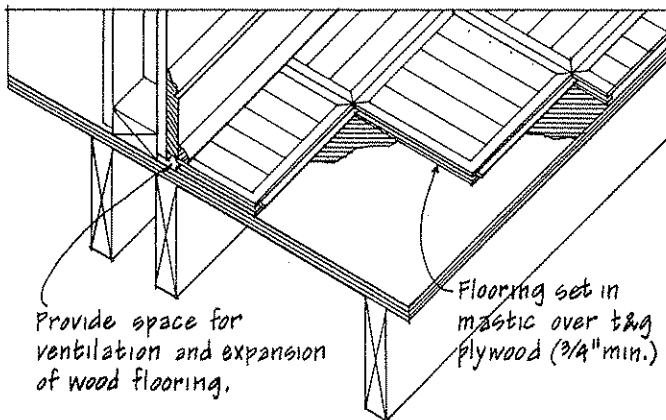
ID.17



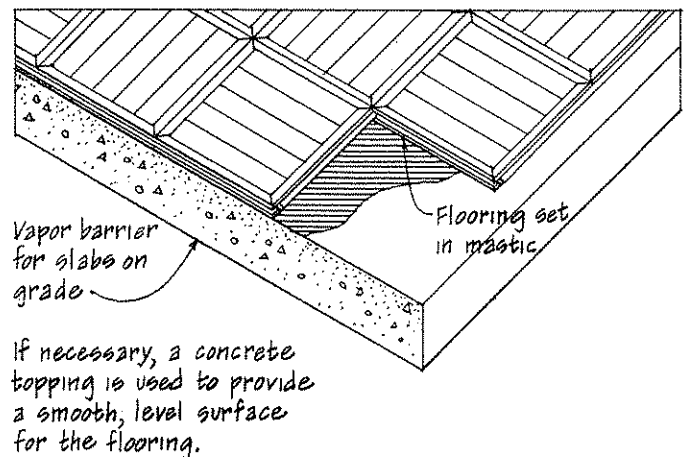
STRIP FLOORING OVER SUBFLOOR AND JOISTS



STRIP FLOORING OVER CONCRETE SLAB



BLOCK FLOORING OVER SUBFLOOR



BLOCK FLOORING OVER CONCRETE SLAB

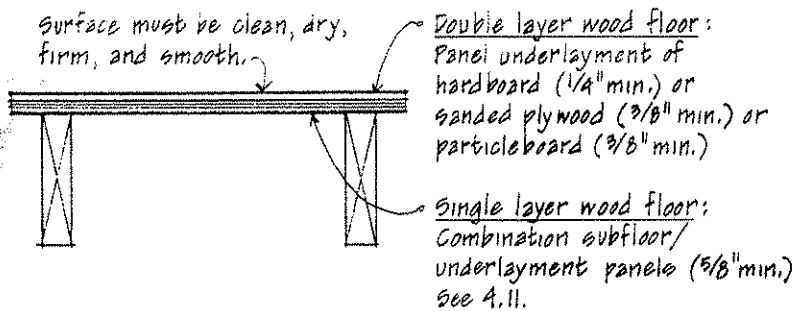
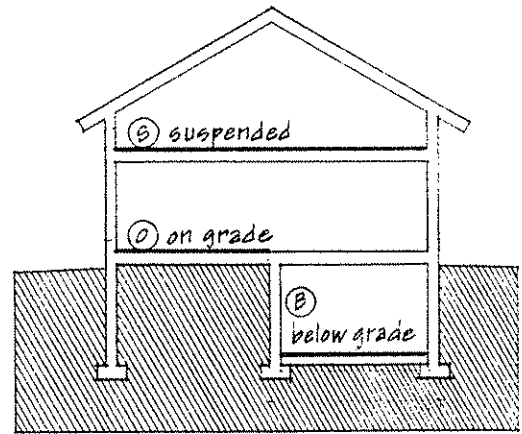
Wood strip and plank flooring requires a wood subfloor or spaced wood sleepers as a base. Plywood or panel subfloors, integral parts of a wood joist floor system, may be laid over other floor systems as well to receive the wood flooring. Treated wood sleepers are usually required over concrete slabs to receive a wood subfloor or the finish wood flooring. This is especially important to protect the flooring from dampness when it is installed on slabs on or below grade.

Wood block flooring requires a clean, dry, smooth, flat surface such as a plywood subfloor or underlayment. While block tiles can be applied to the surface of a dry concrete slab, it is best, especially in basements, to lay the flooring over a plywood subfloor and a vapor barrier set on treated wood sleepers.

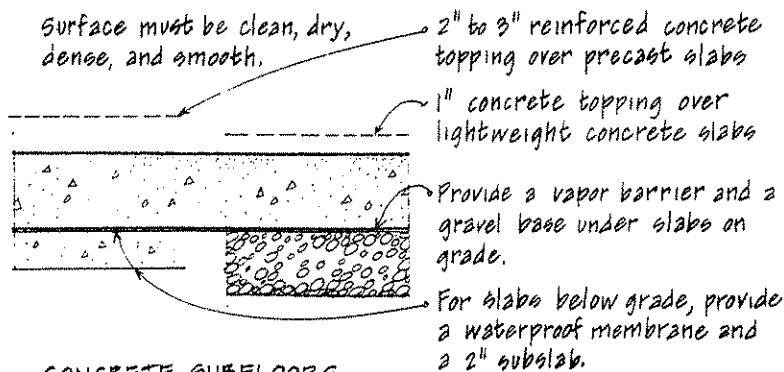
Wood flooring will shrink and swell as its moisture content changes with variations in atmospheric humidity. It should not be installed until the building is enclosed, permanent lighting and the heating plant are installed, and all building materials are dry. The wood flooring should be stored for several days in the spaces where it will be installed to allow the flooring to become acclimated to the interior conditions. As the flooring is installed, space should be provided along the floor's perimeter for ventilation and expansion of the flooring.

11.18 RESILIENT FLOORING

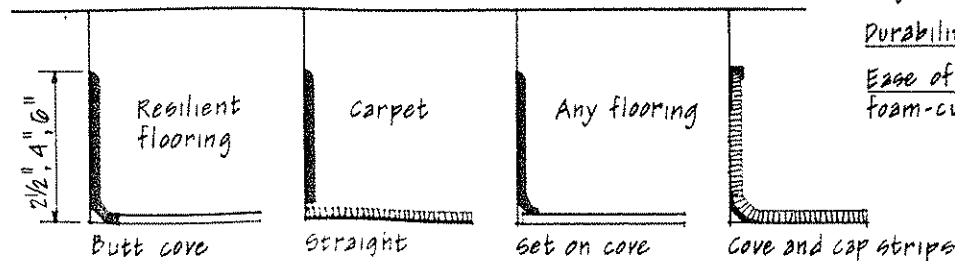
TYPE	COMPONENTS	THICKNESS	SIZES	PERMISSIBLE LOCATION
Vinyl sheet	Vinyl resins w/ fiber back	.065" to .160"	6' to 15' wide	B.O.S
Vinyl tile (homogeneous)	Vinyl resins	1/16" to 1/8"	9" x 9" 12" x 12"	B.O.S
Vinyl tile (composition)	Vinyl resins w/ fillers	.050" to .095"	9" x 9" 12" x 12"	B.O.S
Cork tile	Raw cork and resins	1/8" to 1/4"	6" x 6" 9" x 9"	S
Cork tile w/ vinyl coating	Raw cork w/ vinyl resins	1/8", 3/16"	9" x 9" 12" x 12"	S
Rubber tile	Rubber compound	3/32" to 3/16"	9" x 9" 12" x 12"	B.O.S



WOOD SUBFLOORS



CONCRETE SUBFLOORS



Various resilient flooring accessories are available for use as wall bases, stair nosings and treads, and thresholds.

Resilient flooring materials provide an economical, relatively dense, nonabsorbent flooring surface that is durable and easy to maintain. Their degree of resilience enables them to resist permanent indentation and contributes to their quietness and comfort underfoot. How comfortable a resilient floor covering is, however, depends not only on its resilience but also on its backing and the hardness of the supporting substrate.

None of the resilient flooring types is superior in all respects. Listed below are the types that perform well in specific areas.

Resilience and quietness: cork tile, rubber tile, foam-cushioned vinyl sheet and tile.

Resistance to indentation: solid vinyl tile, foam-cushioned vinyl sheet and tile.

Stain resistance: Vinyl cork tile, vinyl sheet and tile.

Alkali resistance: Vinyl sheet and tile.

Grease resistance: Vinyl sheet and tile, vinyl cork tile.

Durability: Vinyl sheet and tile

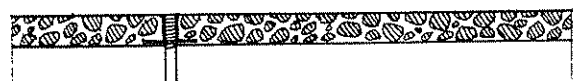
Ease of maintenance: Vinyl cork tile, foam-cushioned vinyl sheet.

TERRAZZO FLOORING

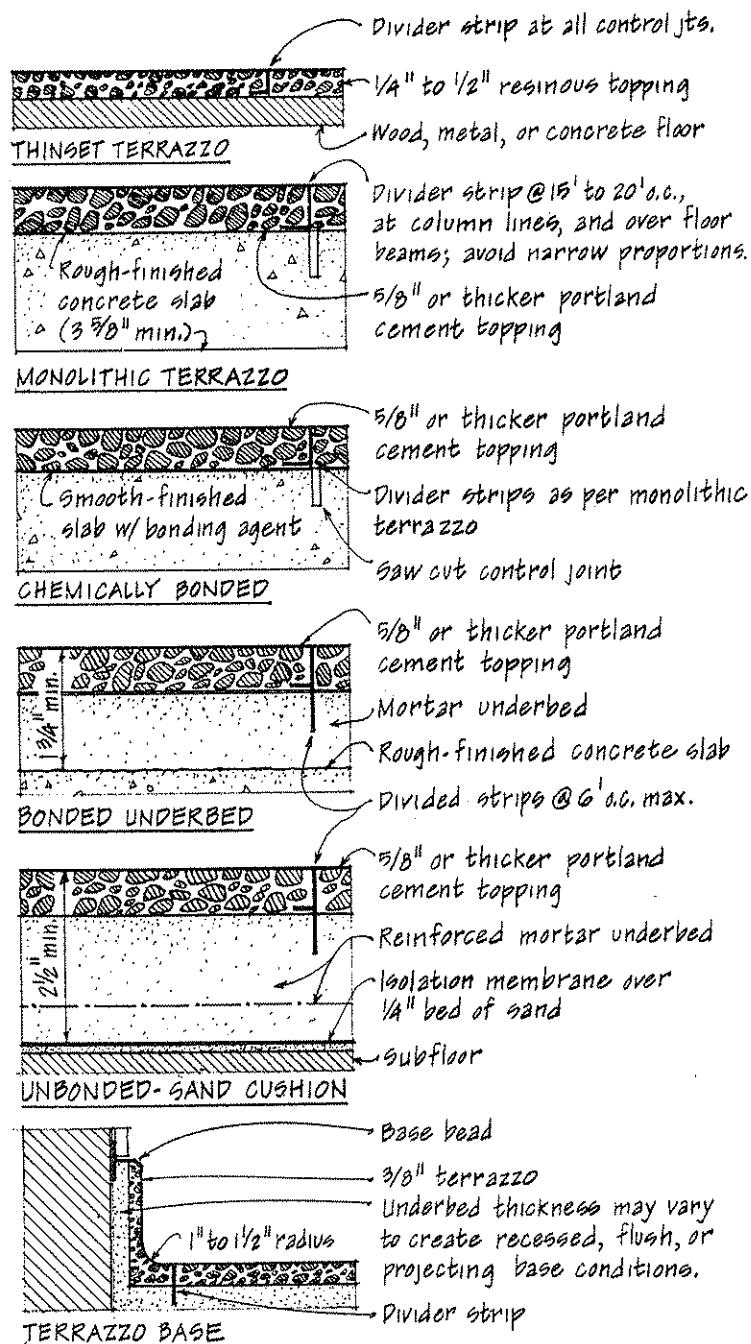
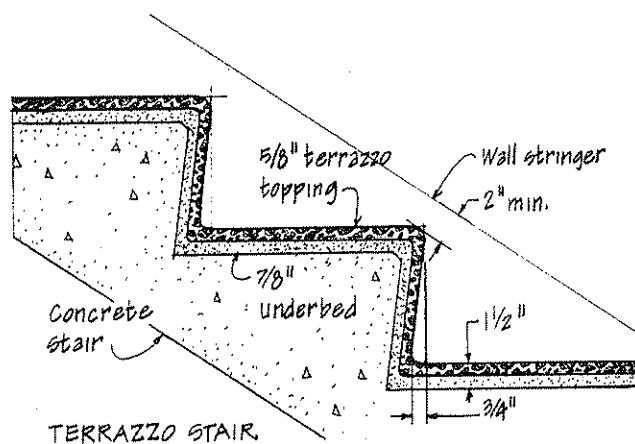
Metal or plastic-tipped divider strips are used to:

- localize shrinkage cracking
- serve as construction joints
- separate the different colors of a floor pattern
- act as decorative elements.

Expansion joints are required over isolation or expansion joints in the subfloor. They consist of a pair of divider strips separated by a resilient material such as neoprene.

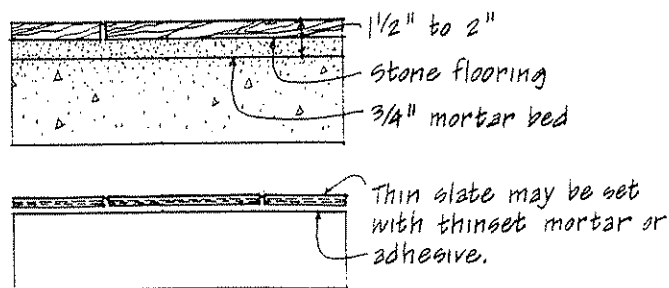


Terrazzo is a ground and polished concrete topping consisting of marble chips or other colored coarse aggregate in a portland cement or resinous binder. It provides a dense, extremely durable, smooth flooring surface whose mottled coloring is controlled by the size and colors of the aggregate and the color of the binder.

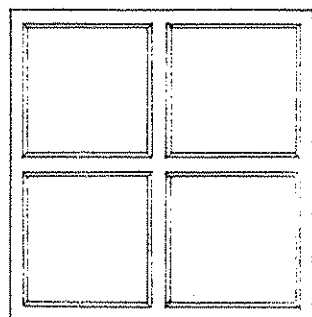


STONE FLOORING

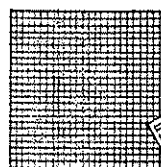
Stone flooring may consist of sandstone, limestone, polished marble or granite, or split face slate. The tiles or slabs may be laid in regular or irregular patterns. Consideration should be given to the stone's weight and the dead load it will impose on the floor structure.



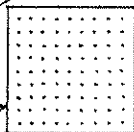
10.20 ACOUSTICAL CEILING TILES



Acoustical ceiling tiles are usually of incombustible glass or mineral fiber. These modular units have perforated, patterned, textured, or fissured faces which allow sound to penetrate into the fiber voids. Because of their light weight and low density, the tiles can be easily damaged. To improve their resistance to humidity, impact, and abrasion, the tiles may be factory-painted or have a ceramic, plastic, or aluminum facing.



Perforated metal pan tile w/ acoustic insulation backing

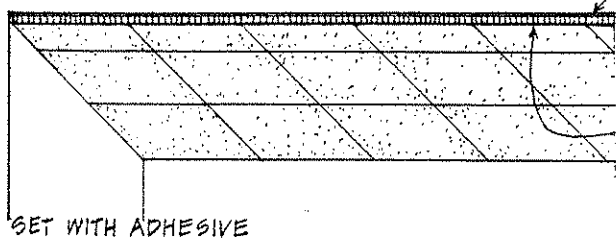


Acoustical ceiling tiles are manufactured in 12"x12", 24"x24", and 24"x48" modules. Tiles based on 20", 30", 48", and 60" are also available.

Typical tile thicknesses: 1/2", 5/8", 3/4". Tiles may have square, beveled, rabbeted, or tongue-and-groove edges.

Consult the ceiling tile manufacturer for:

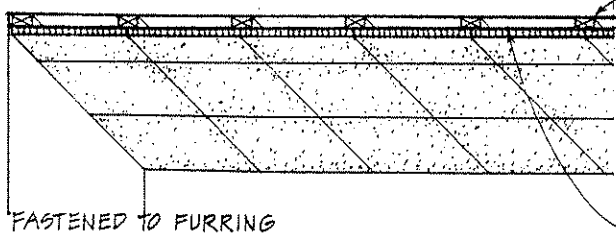
- Sizes, patterns, and finishes
- Noise reduction coefficient (NRC)
- Fire rating
- Light reflectance value
- Suspension system details.



SET WITH ADHESIVE

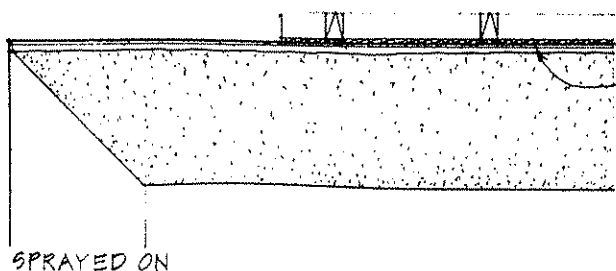
A solid backing such as concrete, plaster, or gypsum board is required.

Tiles are set with a special adhesive that allows a true, flat plane to be maintained even though there may be slight irregularities in the base surface.



FASTENED TO FURRING

1x3 furring strips @ 12" o.c. are used when the base surface is not flat enough or is otherwise unsuitable for the adhesive application of the ceiling tiles. Cross furring and shims may also be required to establish a flat, level base.



SPRAYED ON

Tiles should be backed with building paper to provide a draft-tight ceiling surface.

Acoustical material of mineral or cellulose fibers mixed with a special binder may be sprayed directly onto hard surfaces such as concrete or gypsum board. The material can also be sprayed onto metal lath, which provides better sound absorption and permits curved or irregular ceiling shapes to be formed.

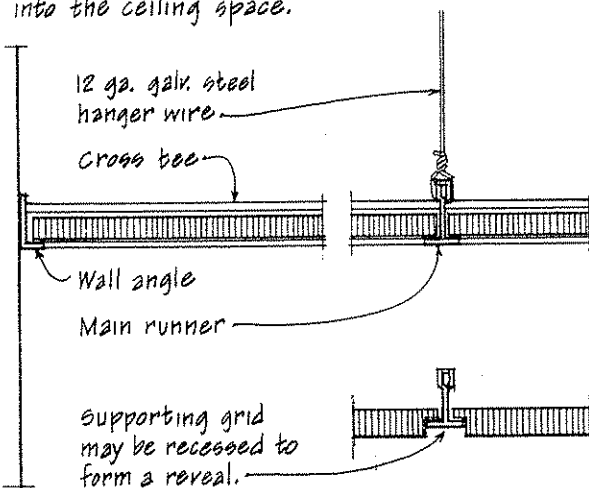
DIRECTION APPLICATION OF ACOUSTICAL CEILING

SUSPENDED ACOUSTICAL TILE CEILINGS

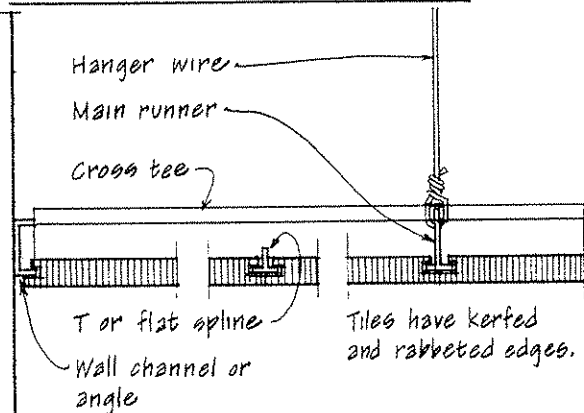
10.21

Acoustical ceiling tiles can be suspended to provide a concealed space for mechanical ductwork, electrical conduit, and plumbing lines. Light fixtures, sprinkler heads, fire detection devices, and sound systems can be recessed into the ceiling plane. The ceiling membrane can be fire rated and provide fire protection for the supporting floor and roof structure. Thus, the ceiling system is able to integrate the functions of lighting, air distribution, acoustical control, and fire protection.

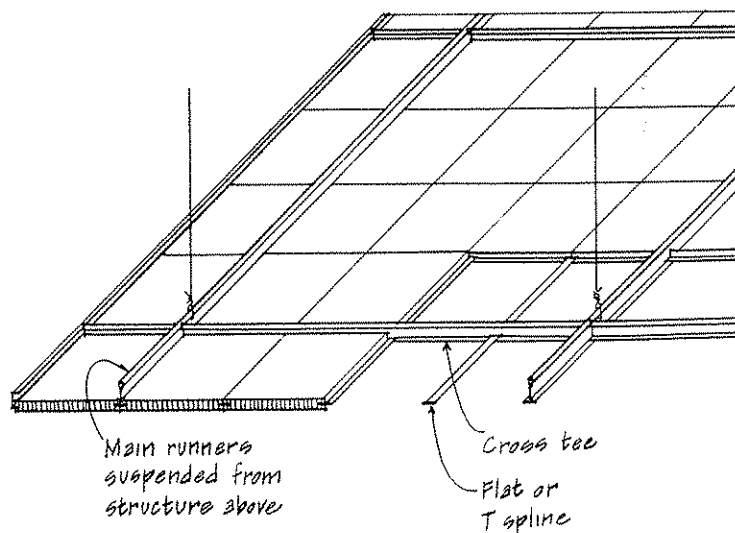
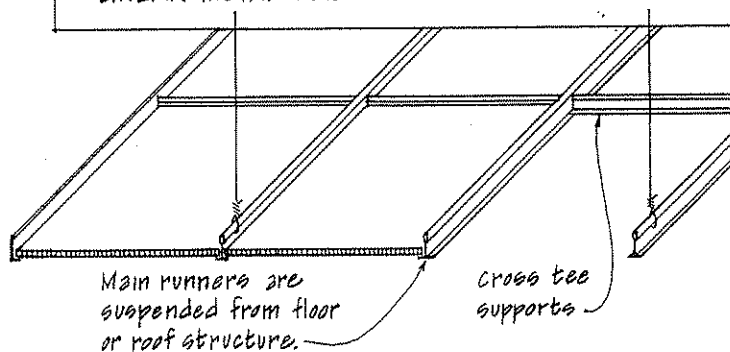
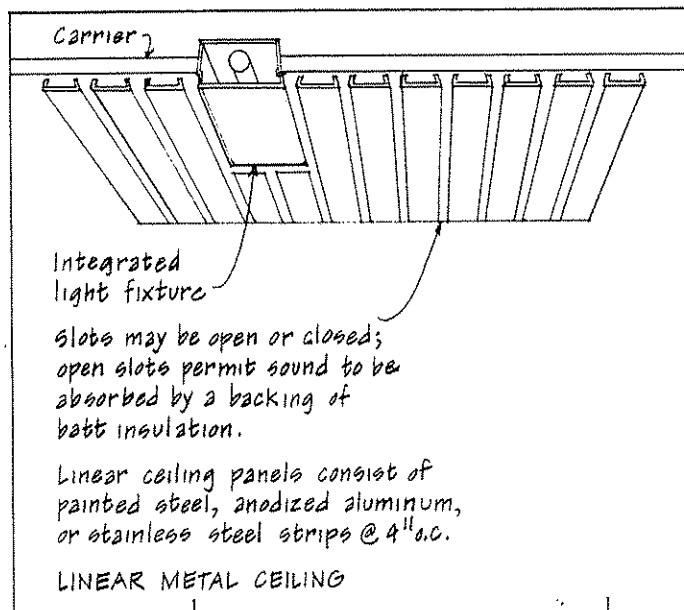
Although the suspension systems of each manufacturer may vary in their details, they all consist of a grid of main channels or runners, cross tees, and splines. This grid, which is hung from the supporting floor or roof structure, may be exposed, semi-concealed, or fully concealed. In most suspension systems, the acoustical tiles are removable for replacement or for access into the ceiling space.



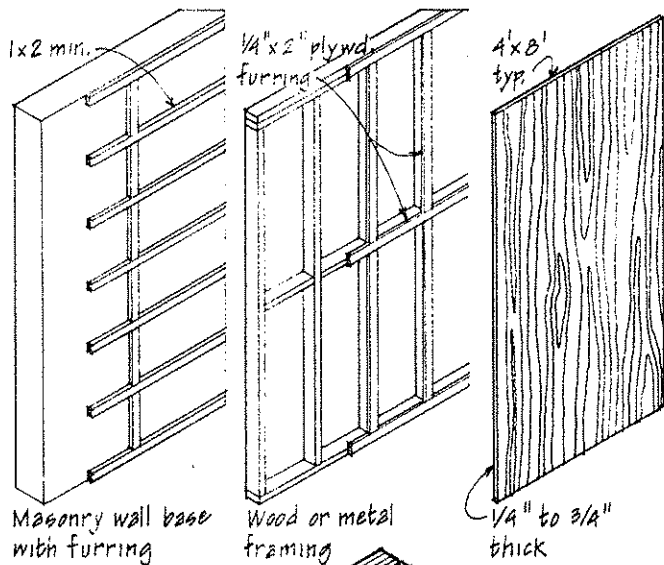
EXPOSED GRID SUSPENSION SYSTEM



CONCEALED GRID SUSPENSION SYSTEM

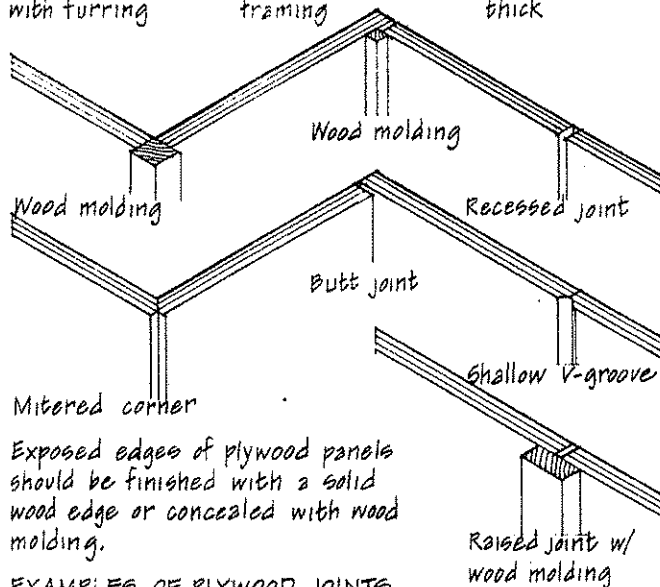


10.22 WOOD PANELING



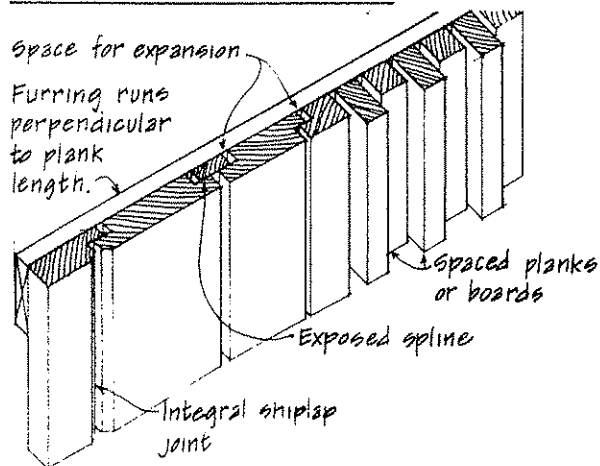
Interior wood paneling may consist of plywood panels or solid wood planks. Plywood panels may be applied directly to wood or metal framing or furring. Furring is required over masonry or concrete walls. Furring may also be used over frame walls when improved thermal insulation properties, greater acoustical isolation, or additional wall depth is desired. The panels are normally fastened with nails or screws although adhesives can be used for greater rigidity. The final appearance of the paneled wall will depend on the treatment of the joints and the panels' grain or figure.

Solid wood planks may also be used for interior paneling. The planks may have square cut, tongue and groove, or shiplap edges. The resulting wall pattern and texture will depend on the plank width, orientation, spacing, and joint details.



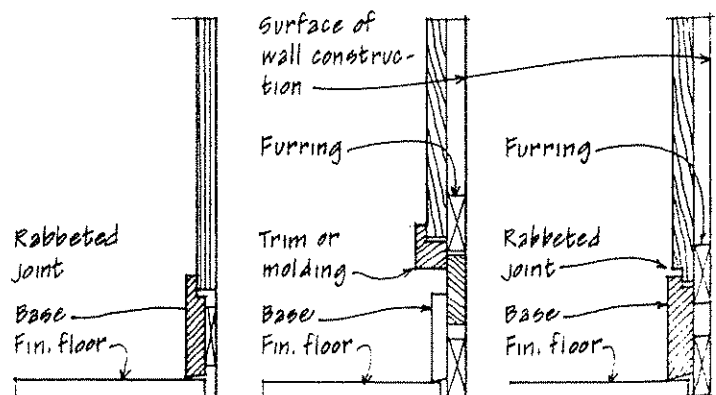
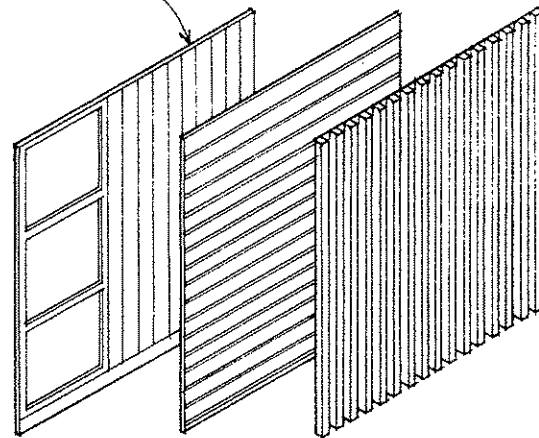
Exposed edges of plywood panels should be finished with a solid wood edge or concealed with wood molding.

EXAMPLES OF PLYWOOD JOINTS



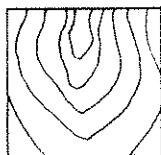
EXAMPLES OF WOOD PLANK JOINTS

Space should be provided for expansion of wood.

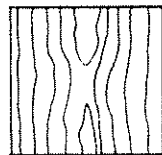
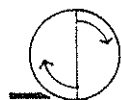


EXAMPLES OF BASE DETAILS

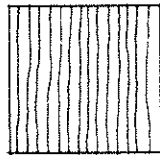
Details at ceiling and horizontal rails are similar.



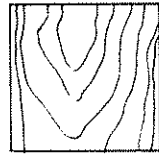
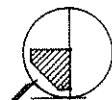
Rotary



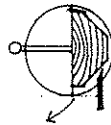
Flat slicing



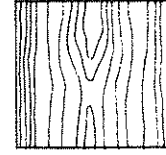
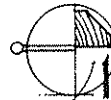
Quarter slicing



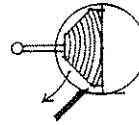
Half round slicing



Rift cut



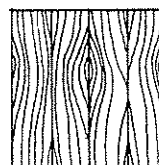
Back cut



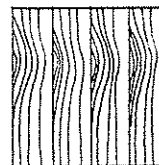
WOOD GRAIN FIGURES

Different wood grain figures may be produced by varying the way in which the wood veneer is cut from a log.

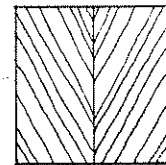
The appearance of naturally finished plywood paneling depends on the species of wood used for the face veneer, its grain figure, and the pattern developed by the way in which the panels are matched or arranged.



Book



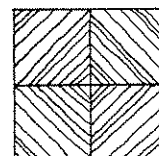
Slip



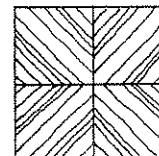
V pattern

VENEER GRADES FOR PLYWOOD

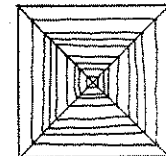
- N - Select, smooth surface for natural finishes
- A - Smooth face suitable for painting
- B - Solid surface utility panel



Diamond



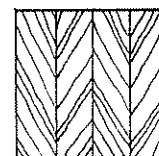
Reverse diamond



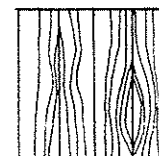
Box

HARDWOOD VENEER GRADES

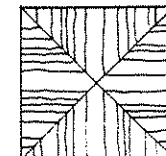
- Premium grade** High quality veneer with only slight imperfections; multipiece faces must be matched.
- Good grade** Suitable for natural finishes; matching of veneer faces is not required, but no sharp contrasts in color are allowed.
- Sound grade (#2)** Sound, smooth surface suitable for painting.
- Utility grade (#3)** May have open defects, but these are limited in size.



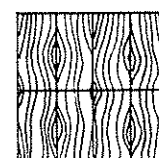
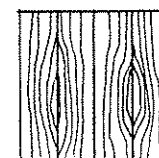
Herringbone



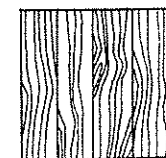
Center



Reverse box

Vertical butt
Horizontal book

Balance

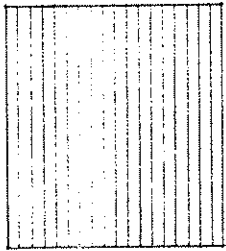


Random

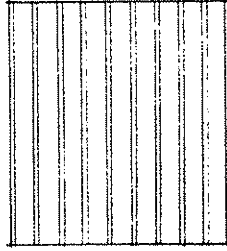
VENEER MATCHING PATTERNS

110.24

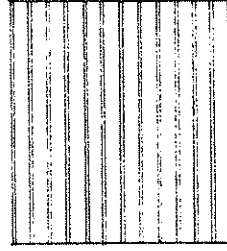
PLYWOOD SIDING



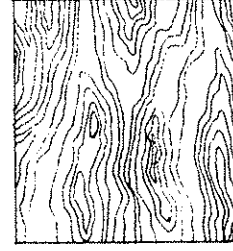
Texture 1-II $\frac{5}{8}$ "
 $\frac{1}{4}$ " deep, $\frac{3}{8}$ " wide
 grooves @ 4" or 8" o.c.



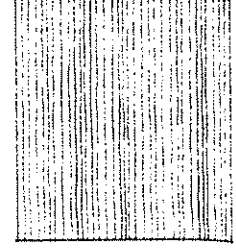
Reverse board & batten
 $\frac{1}{4}$ " deep, 1" wide
 grooves @ 12" o.c.



Channel groove $\frac{3}{8}$ "
 $\frac{1}{16}$ " deep, $\frac{3}{8}$ " wide
 grooves @ 4" or 8" o.c.



Rough sawn

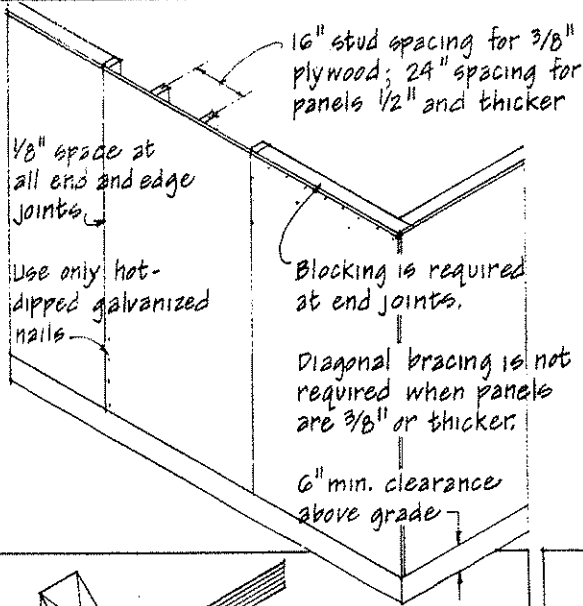


Striated

MDO is a medium density overlay panel suitable for painting.

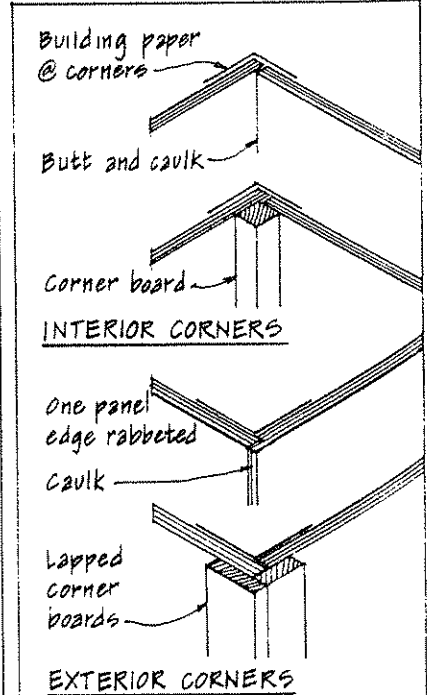
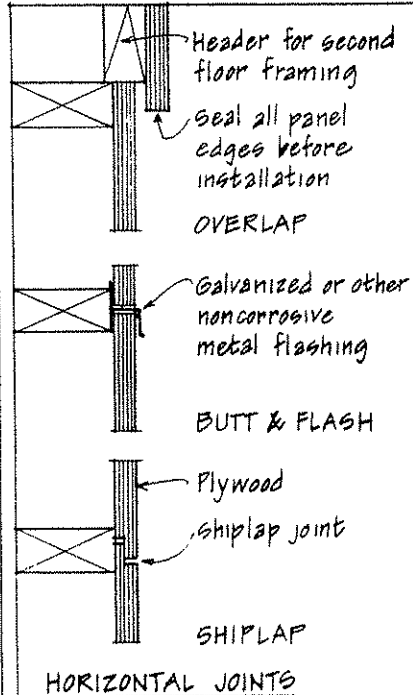
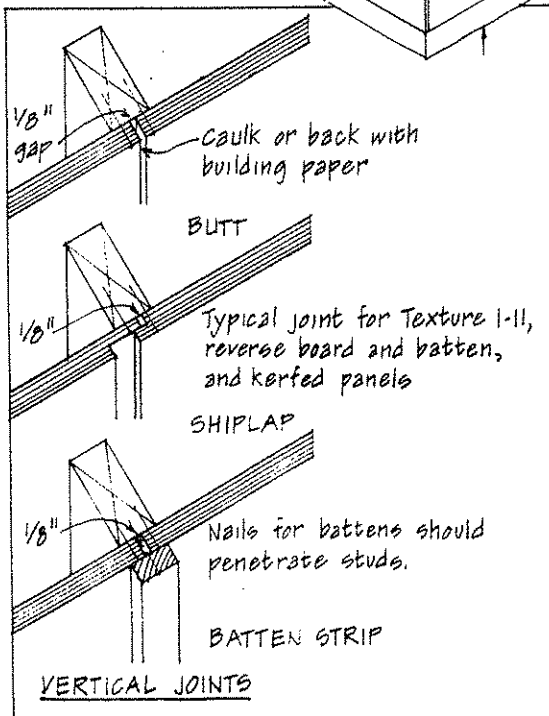
PLYWOOD PANEL SIDING PATTERNS

PANEL TEXTURES

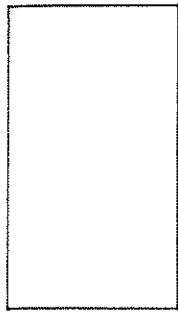


Exterior-grade plywood siding panels are typically 4' x 8', although 9' and 10' lengths are available. The most common patterns imitate vertical board siding. The panel surface may have a grooved, rough sawn, brushed, or striated texture, and may be stained or treated with a clear water-repellant finish. Medium density overlay (MDO) panels are suitable for paint finishes.

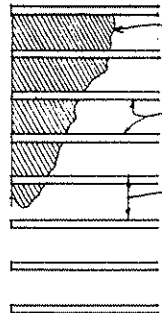
Horizontal joints, which must be protected by flashing or other means, are very noticeable. These horizontal lines should therefore be coordinated with other exterior wall elements such as window and door openings.



WOOD SHINGLE SIDING



Plywood or
nailable fiber-
board



Spaced sheathing is required
over non-nailable sheathing or
siding.

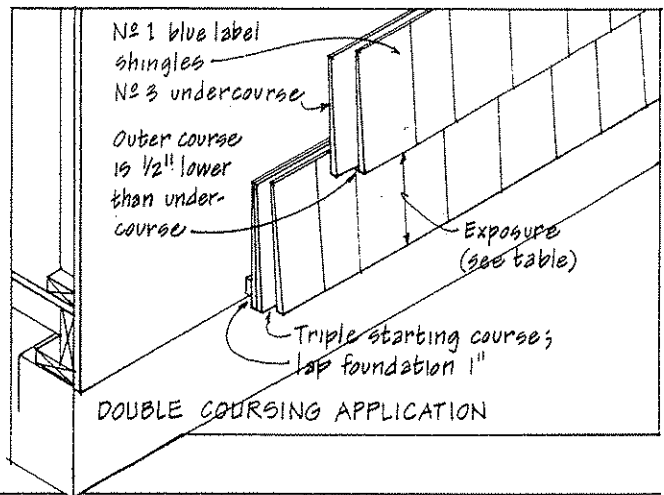
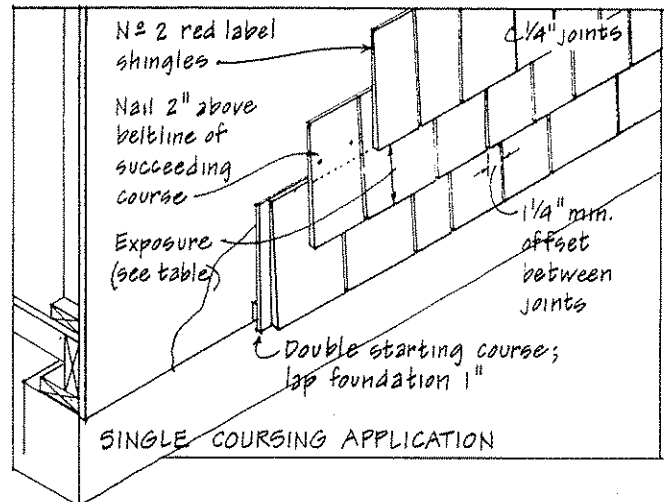
Breathing-type
building paper
1x3s or 1x4s
nailed to studs
Spacing equals
shingle exposure

TYPES OF SHEATHING

On exterior walls, wood shingles are laid in uniform courses that resemble lap siding. As with lap siding, the courses should be adjusted to meet the heads and sills of window openings and other horizontal bands neatly. The shingles may be stained or painted. Premium-grade shingles can be left unpainted to weather naturally.

Wood shingle siding may be applied in single or double coursing, with the following exposures:

SHINGLE LENGTH	SINGLE COURSING	DOUBLE COURSING
• 16"	6" to 7 1/2"	8" to 12"
• 18"	6" to 8 1/2"	9" to 14"
• 24"	8" to 11 1/2"	12" to 20"



Dimension and fancy butt shingles are cut to uniform widths and shapes. They are used on walls to create certain effects such as scalloped or fishscale textures.



Square



Arrow



Diamond



Round



Octagonal



Half cove

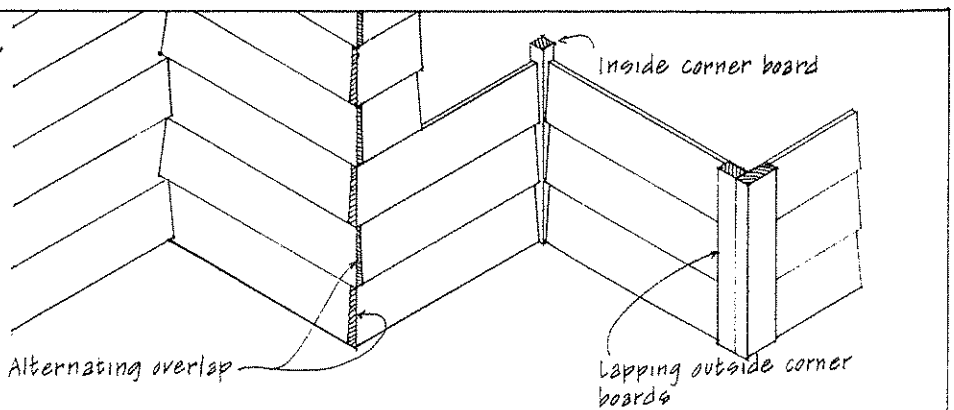


Hexagonal



Fishscale

At corners, alternating courses are lapped over the adjacent corner shingles on the other side. Exposed edges should be treated. Corner boards can also be used to receive the shingles at both interior and exterior corners. Building paper should be used to flash corners and wherever the shingles abut wood trim.



10.26 WOOD BEVEL SIDING

Wall sheathing and a permeable building paper that allows any water vapor in wall to escape to the outside.

Frieze board rabbeted or turned out to receive top course

Metal flashing
Extend up 2" beneath siding

Caulk butt joints or back w/ bldg. paper

Butt joints should fall over a stud

Min. 6" clearance to grade

Continuous starter strip

* Use only hot-dipped galvanized or other corrosion-resistant nails

Bevel siding, also known as lap siding, is made by cutting a board diagonally across its cross section so that the siding has one thin edge and one thick edge. This thick or butt edge may be rabbeted for a shiplap joint. The rough, resawn side can be exposed for stain finishes, while the smooth, planed side can be either painted or stained.

Bevel siding should lap a minimum of 1". The actual exposure, however, should be adjusted so that the courses align neatly with heads and sills of windows, frieze boards, and other horizontal bands.

FACE DIMENSION	BUTT END	
	Nominal	Actual
4"	3 1/2"	15/32"
5"	4 1/2"	15/32"
6"	5 1/2"	9/16"
8"	7 1/4"	3/4"
10"	9 1/4"	3/4"

Butt 3/16"

Mitered corner

Extra stud for nailing of siding ends

Caulk or back butt joints w/ bldg. paper

Lapping corner boards

Corner strip

BEVEL SIDING APPLICATION

CORNERS

Sheathing
Building paper
1" min. lap;
lap wide boards
1 1/2" to 2"

Face nail -
Nail should
clear undercourse

For rabbeted
bevel siding,
provide 1/8" space
for expansion

Starter strip
for first course

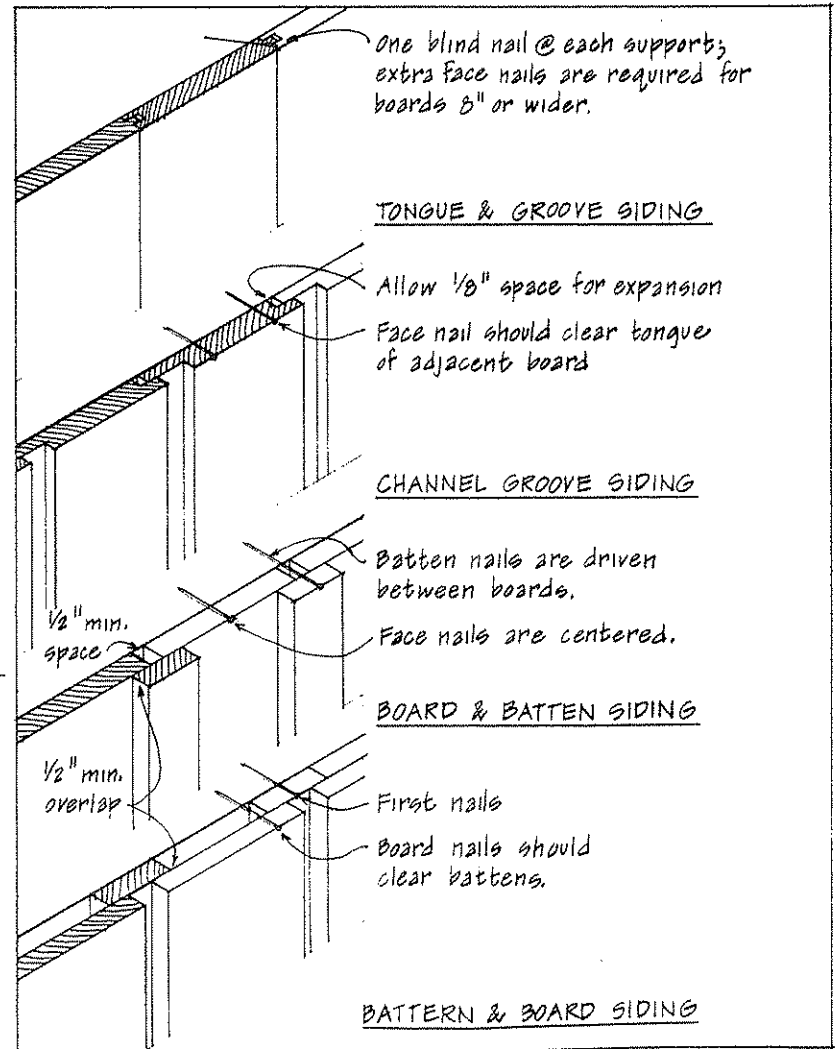
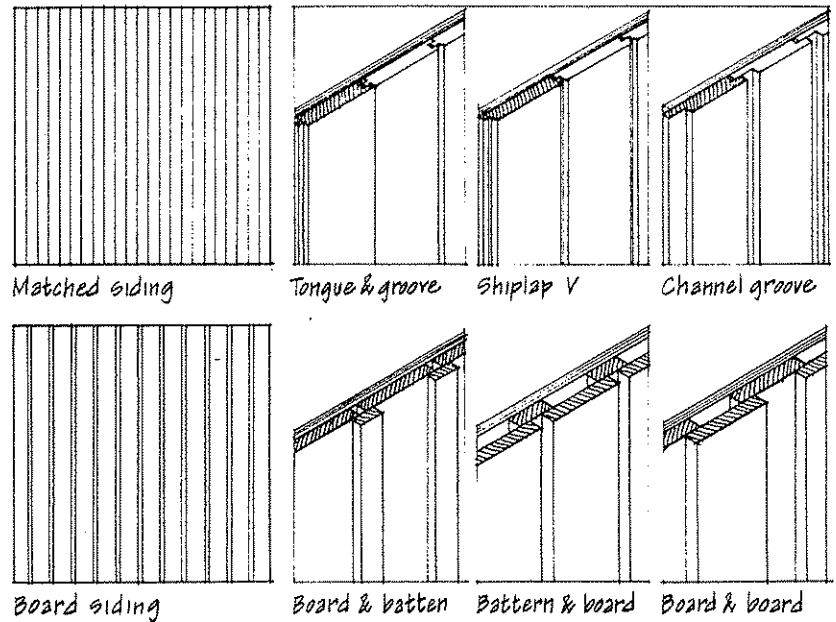
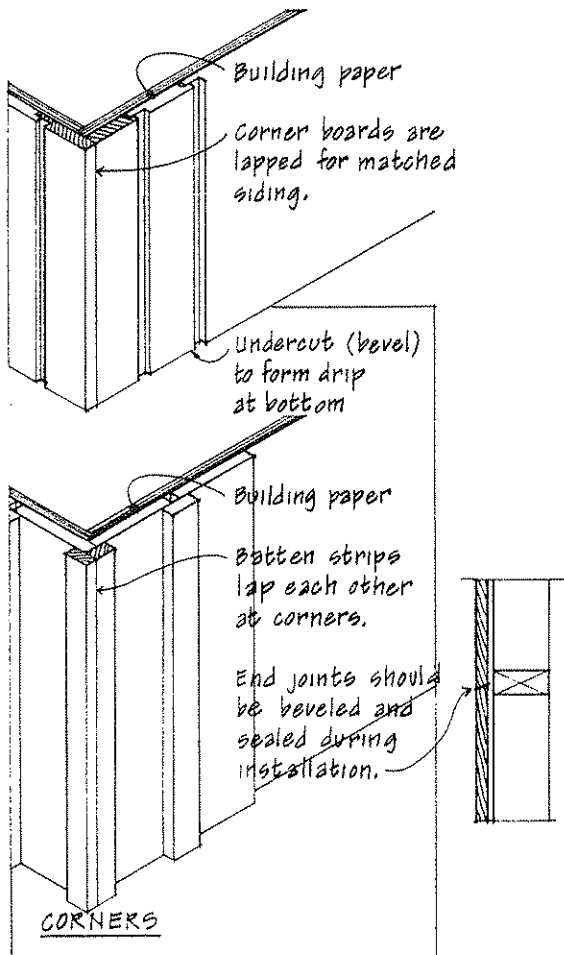
WOOD VERTICAL SIDING

10.27

Vertical siding can be laid in various patterns. Matched boards that interlap or interlock can have flush, V-groove, or beaded joints. Square-edged boards can be used with other boards or battens to protect their vertical joints and form board-and-board or board-and-batten patterns.

While horizontal siding is nailed directly to the wall studs, vertical siding requires solid blocking at 24" o.c., or plywood sheathing at least $\frac{5}{8}$ " or $\frac{3}{4}$ " thicker. Over thinner sheathing, 1x4 furring can be used at 24" o.c. A permeable building paper that allows water vapor to escape to the outside is used under the siding.

As with other siding materials, only hot-dipped galvanized or other corrosion-resistant nails should be used. Treat ends and edges of siding, and the backs of batten strips, with a preservative.



DowelSquareHalf-round

Use to conceal vertical and horizontal joints.

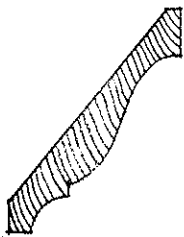
Quarter-round

Use to finish inside corners; base shoe finishes base trim at the floor line.

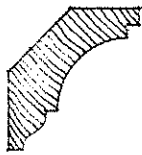
Shoe

For use as trim, a variety of stock wood moldings are available at millwork shops. They vary in section, length, and species of wood. They can be used singly or be combined to form more complex sections. In addition to these stock sections, wood moldings can be milled to custom specifications.

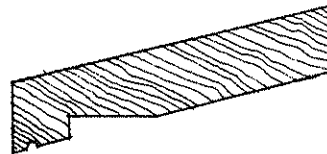
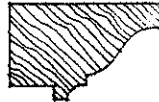
The type of wood used for trim depends on the type of finish to be applied to the woodwork. For painted finishes, the wood should be close-grained, smooth, and free of pitch streaks or other imperfections. If the woodwork is to receive a transparent or natural finish, the wood should have a uniform color, an attractive grain figure, and a degree of hardness.

Crown

Use at the meeting of wall and ceiling surfaces, and at mantels.

Cap

Use over windows, doors, and at the tops of wainscots.

Sill

The bottom trim of window and door openings.

Stool

The interior trim at the bottom of windows.

Casing

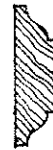
Use to trim head and side jambs of windows and doors.

Chair rails

Use to protect a wall surface from chair backs.

Stop

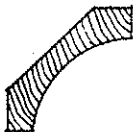
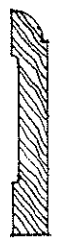
Use at jambs to guide windows and stop doors.

Panel strip

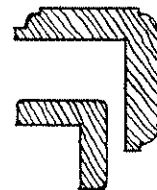
Use to conceal joints in paneling.

Base

Use where sidewalls meet the floor, and as window and door casings.

Cove

Use where surfaces meet at 90°.

Corner

Use at exterior corners.

Screen

Use to finish the screening on windows and doors.

INTERIOR WOOD TRIM

10.29

Interior trim is normally applied after the finish walls, ceiling, and flooring are in place. Although decorative in nature, interior trim also serves to conceal, finish, and perfect the joints between interior materials. Common types of interior trim include:

CORNICES

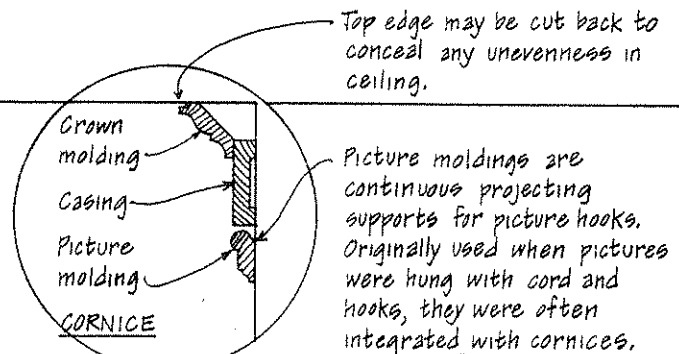
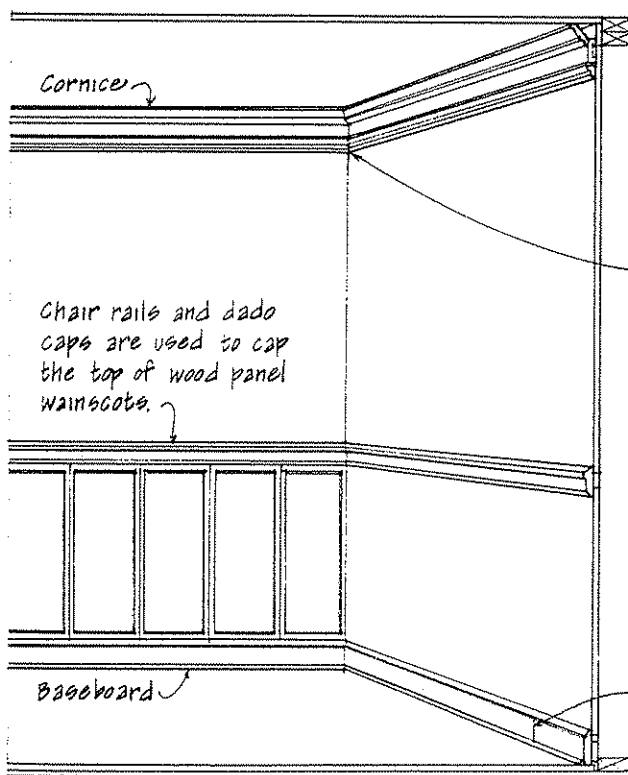
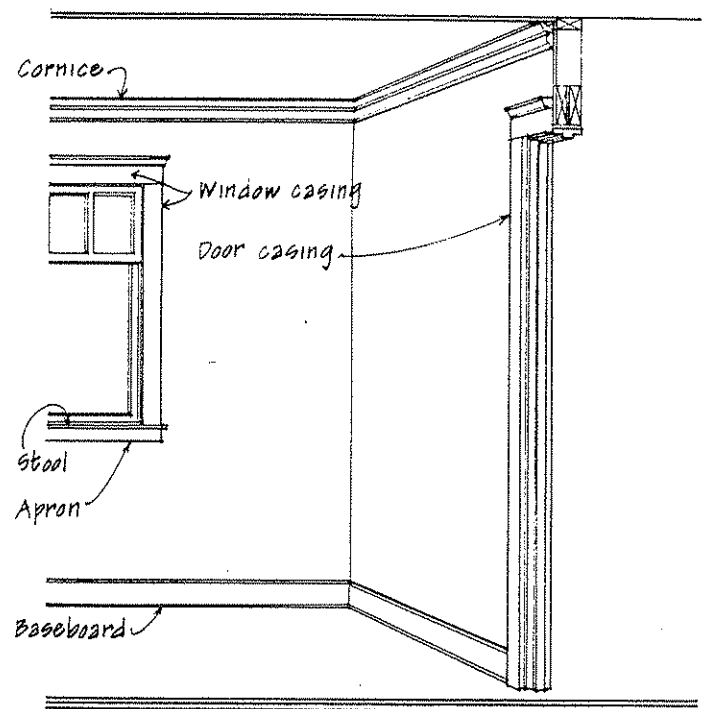
Cornices are used to finish the joint between ceilings and walls, especially when they are of different materials.

DOOR AND WINDOW TRIM

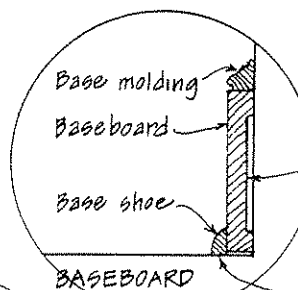
Head and side jamb casings conceal and finish the joint or gap between door and window frames and the surrounding wall surface. Stools and aprons are used to finish the joint between window sills and interior walls.

BASEBOARDS

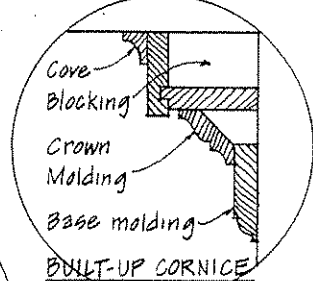
Baseboards and base shoes conceal and finish the joint between interior walls and the flooring.



Inside corners of shaped moldings are coped (cut to the profile of the adjoining trim).



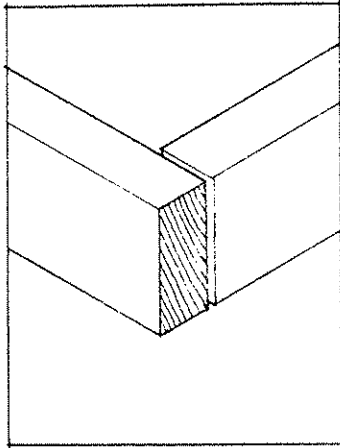
Joints in long runs of trim are face mitered.



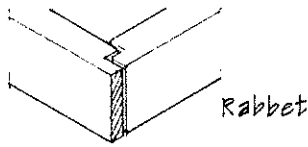
Cupped back gives a wider trim a degree of flex and allows it to fit neatly against a wall surface.

Flexible base shoe can conform to irregularities in floor surface.

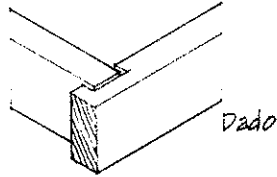
100 .50 WOOD JOINTS



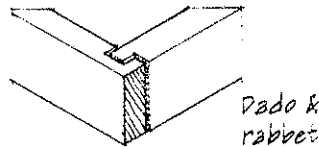
RIGHT ANGLE JOINTS



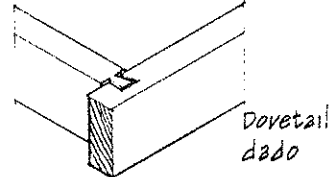
Rabbet



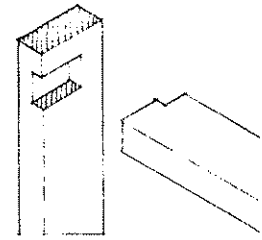
Dado



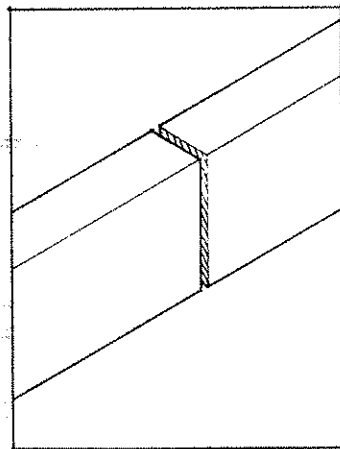
Dado & rabbet



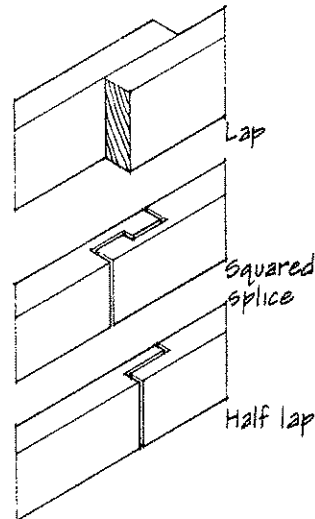
Dovetail dado



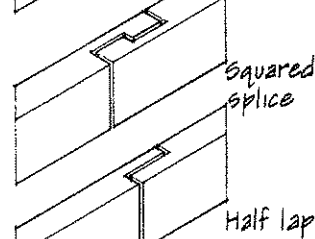
Stopped dado



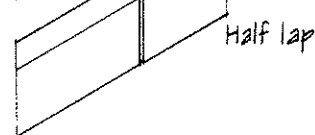
END JOINTS



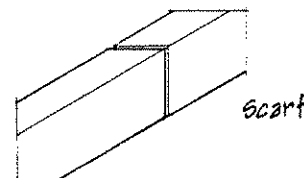
Lap



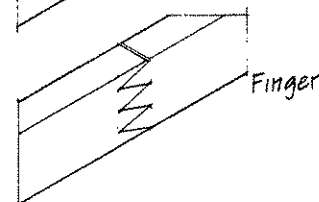
Squared splice



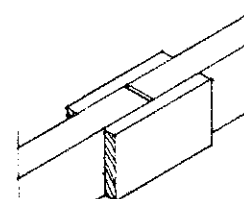
Half lap



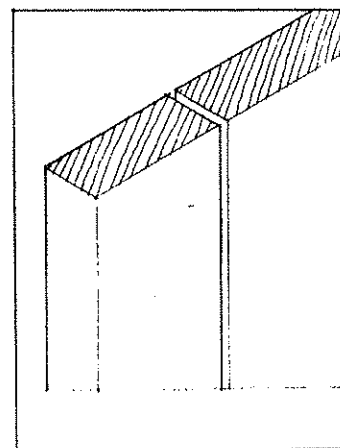
Scarf



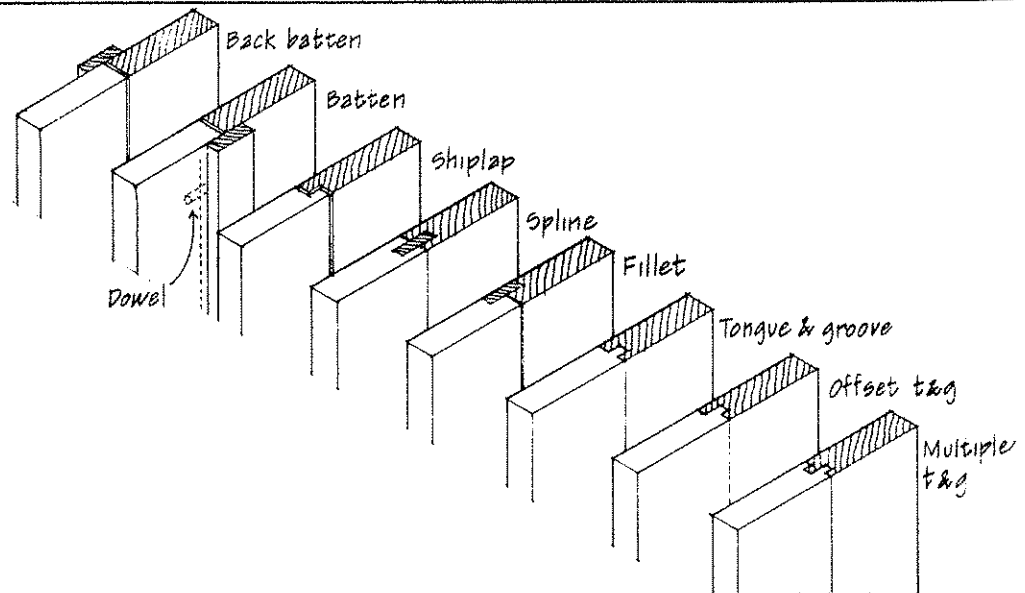
Finger



Splice



EDGE JOINTS



Back batten

Batten

Shiplap

Spline

Fillet

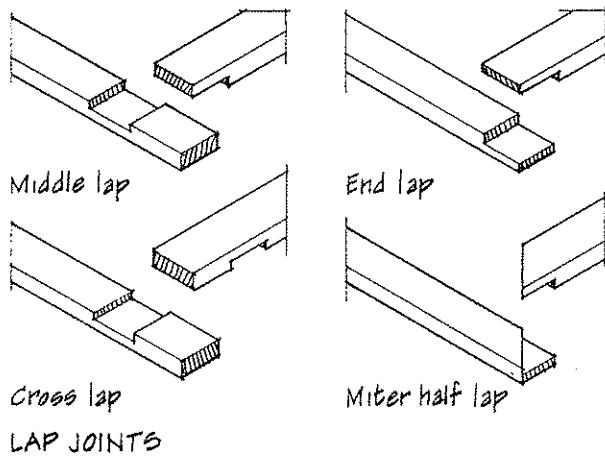
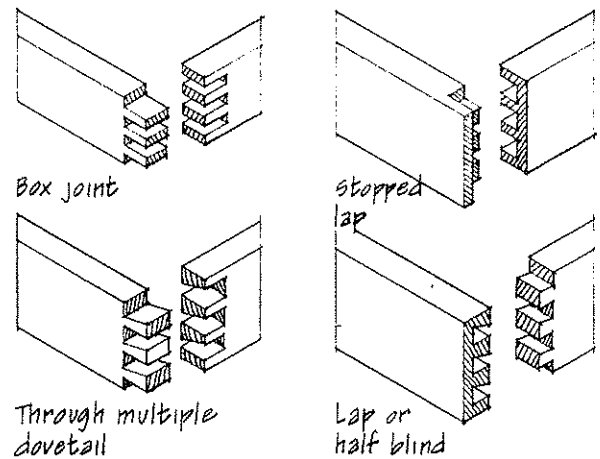
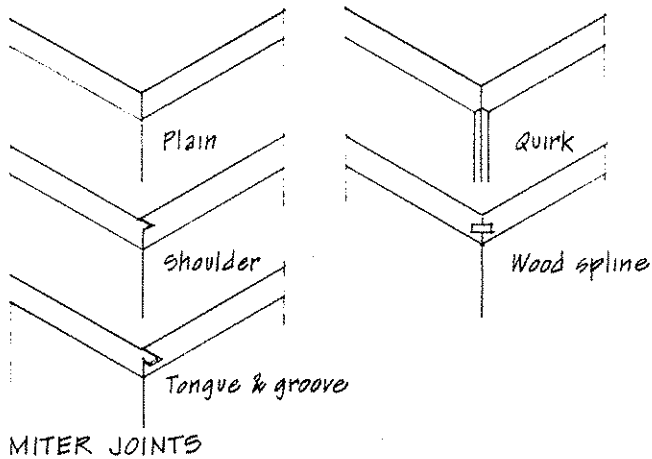
Tongue & groove

Offset t&g

Multiple t&g

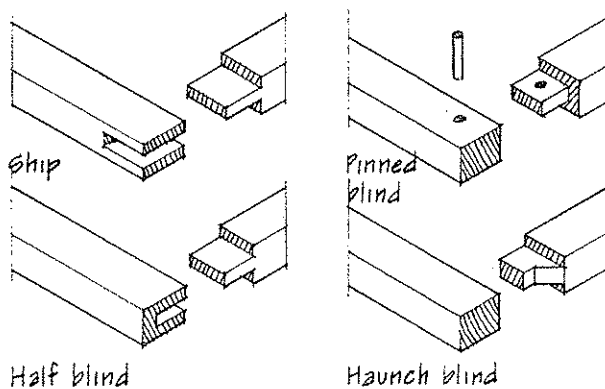
WOOD JOINTS

10.51



The strength and rigidity of ordinary wood framing are more important than its appearance since it is normally covered with a finish surface. In finish trim, cabinetry, and furniture work, however, a wood joint's appearance becomes just as important as its strength. Small scale work requires more sophisticated and refined joints which present a clean appearance.

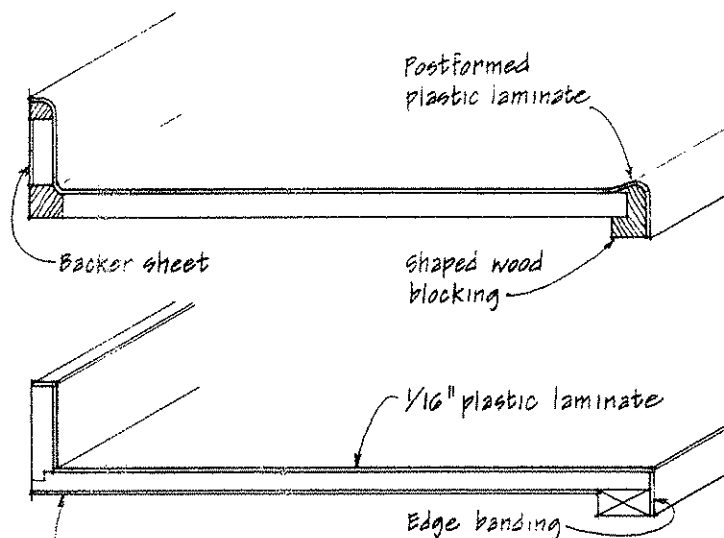
Wood joints can express the manner in which the members are connected, or they can be relatively inconspicuous. In either case, they must remain tight. If they open due to the wood's shrinkage or structural movement, they become both weaker and more noticeable.



In designing and constructing a wood joint, it is important to understand the basic nature of the forces (compressive, tensile, shear) acting on the joint, and to comprehend their relationship to the wood grain's direction. (See 12.2.)

MORTISE AND TENON JOINTS

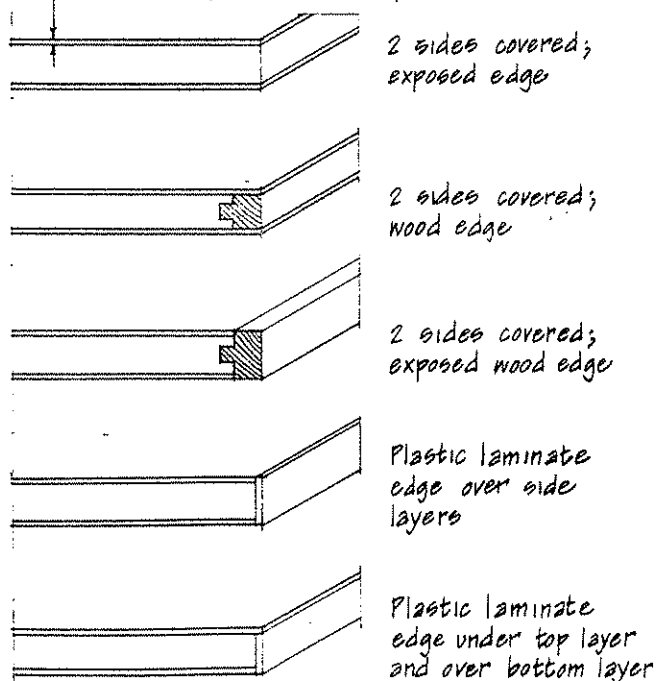
10.52 PLASTIC LAMINATE



A backer sheet of plastic laminate should be applied to the opposite side of unsupported panels to keep them from warping.

PLASTIC LAMINATE COUNTERTOPS

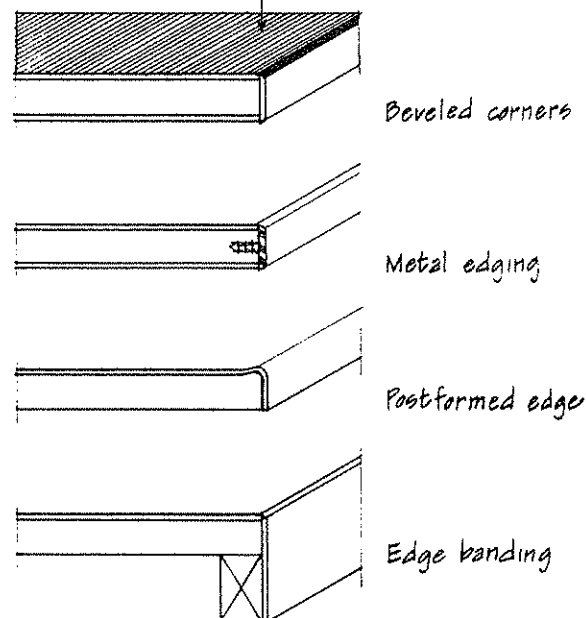
Thicknesses: $\frac{1}{16}$ " for horizontal applications (counter and table tops)
 $\frac{1}{32}$ " for vertical applications (door and wall panels)



Plastic laminates consist of layers of different materials (kraft paper, foil, cover overlay of printed paper, wood veneer, or fabric) impregnated with phenolic and melamine plastics and cured under intense heat and pressure. Plastic laminates provide a hard, durable, heat- and water-resistant surface covering for countertops, furniture, doors, and wall panels. They may be applied to smooth plywood, hard-board, particleboard, and other common core materials. They may be bonded with contact adhesive in the field or with thermosetting adhesive, under pressure, in the shop.

Plastic laminate surfaces with tight rolls and bends should be postformed during manufacture and bonded with thermosetting adhesive. Postformed plastic laminate, $\frac{1}{20}$ " thick, may be bent to a radius as small as $\frac{3}{4}$ ". Plastic laminate edge banding may be bent to a radius of 3", or smaller if heated.

A wide range of colors and patterns is available in glossy, satin, low-glare, or textured finishes.

EDGE TREATMENTS FOR PLASTIC LAMINATE COVERED PANELS

MECHANICAL & ELECTRICAL SYSTEMS

11

This chapter discusses the mechanical and electrical systems which are required to maintain the necessary conditions of environmental comfort, health, and safety for a building's occupants. The intent is not to provide a complete design manual but to outline those factors which should be considered for the successful operation of these systems and their integration with a building's other systems.

Heating, ventilating, and air-conditioning systems condition the interior spaces of a building for the environmental comfort of the occupants. A potable water supply is essential for human consumption and sanitation. The efficient disposal of fluid waste and organic matter is necessary in order to maintain sanitary conditions within a building and in the surrounding area. Electrical systems furnish light and heat for a building's occupants, and power to run its machines.

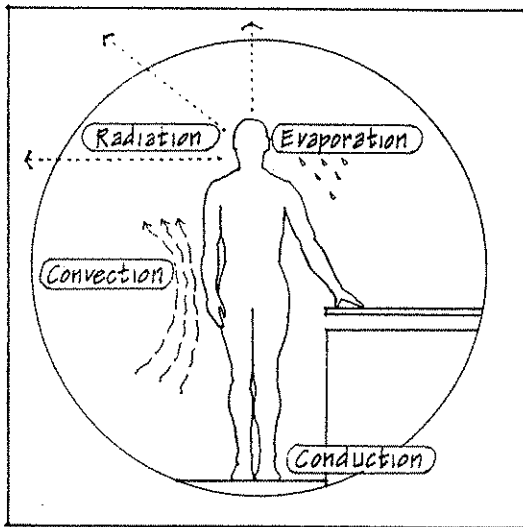
These systems require a significant amount of space. Because much of these systems' hardware is normally hidden from view—within concealed construction spaces or special rooms—the layout of these systems should be carefully integrated with each other as well as with a building's structural and enclosure systems.

III.2 ENVIRONMENTAL COMFORT

- ① Temperature of the surrounding air
- ② Mean radiant temperature of the surrounding surfaces
- ③ Relative humidity of the air
- ④ Air motion
- ⑤ Dust
- ⑥ Odors

The mechanical system of a building includes the heating, cooling, ventilating, and air-conditioning equipment used to control the environmental comfort factors listed to the left. The first four factors are of primary importance in determining thermal comfort, and may also be controlled by a building's siting, materials, and construction assemblies.

Balancing heat loss and heat gain to arrive at a comfortable temperature is the first step in achieving thermal comfort. The human body can lose heat by radiation, convection, conduction, or evaporation.



RADIATION: The transmission of heat energy through the air from a warm surface to cooler surfaces.

- Light colors reflect while dark colors absorb heat; poor reflectors make good radiators.
- Radiant heat cannot go around corners and is not affected by air motion.

CONVECTION: The transmission of heat from a warm surface to the surrounding air.

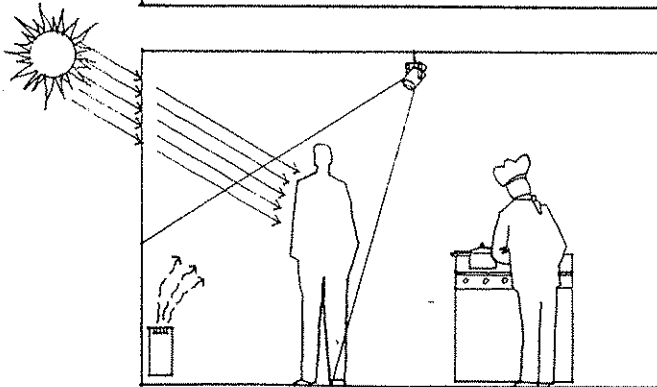
- Large temperature differentials and increased air motion induce more heat transmission by convection.

CONDUCTION: The transmission of heat from a warm body directly to a cooler body.

- Conduction has little effect on actual heat loss.

EVAPORATION: The transmission of heat through the evaporative process of moisture turning into water vapor.

- Evaporation is an important factor when high temperatures, humidity, and activity levels exist.
- Heat loss by evaporation increases with air motion.



Source of heat within a building include:

- Solar radiation through a building's wall and roof assemblies.
- Building equipment such as heaters, light fixtures, and ranges.
- Human activity.

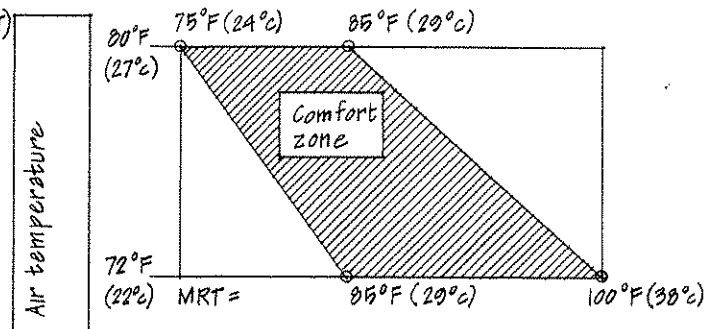
The objective of an air-conditioning system is to adjust the thermal comfort factors according to outdoor and indoor conditions and the level of human activity so that comfort-zone conditions exist within a space.

The following relationships between the four primary thermal comfort factors can be used to describe recommended comfort zones.

- Air temperature is controlled by the supply of warm or cool air to a space through various media: air, water, or electricity.
- Mean radiant temperature of surfaces is controlled by using radiant heat panels (hot water or electrical resistance heating) or by washing surfaces with warm air.
- Relative humidity is controlled by the introduction of water vapor, or its removal, by ventilation.
- Air motion is controlled by mechanical ventilation.

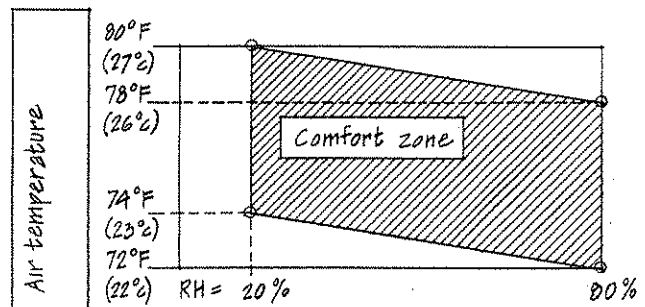
AIR TEMPERATURE AND MEAN RADIANT TEMPERATURE (MRT)

- The higher the mean radiant temperature of the surrounding surfaces, the cooler the air temperature should be.
- MRT has about 40% more effect on comfort than air temperature.
- In cold weather, the MRT of the interior surfaces of exterior walls should not be more than 5°F (9°C) below the indoor air temperature.



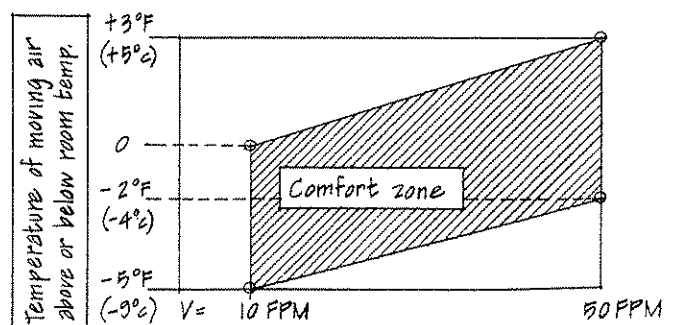
AIR TEMPERATURE AND RELATIVE HUMIDITY (RH)

- The higher the relative humidity of a space, the lower the air temperature should be.
- RH is more critical at high temperatures than within the normal temperature range.
- Low humidity (<20%) can have undesirable effects such as the buildup of static electricity and the drying out of wood; high humidity can cause condensation problems.



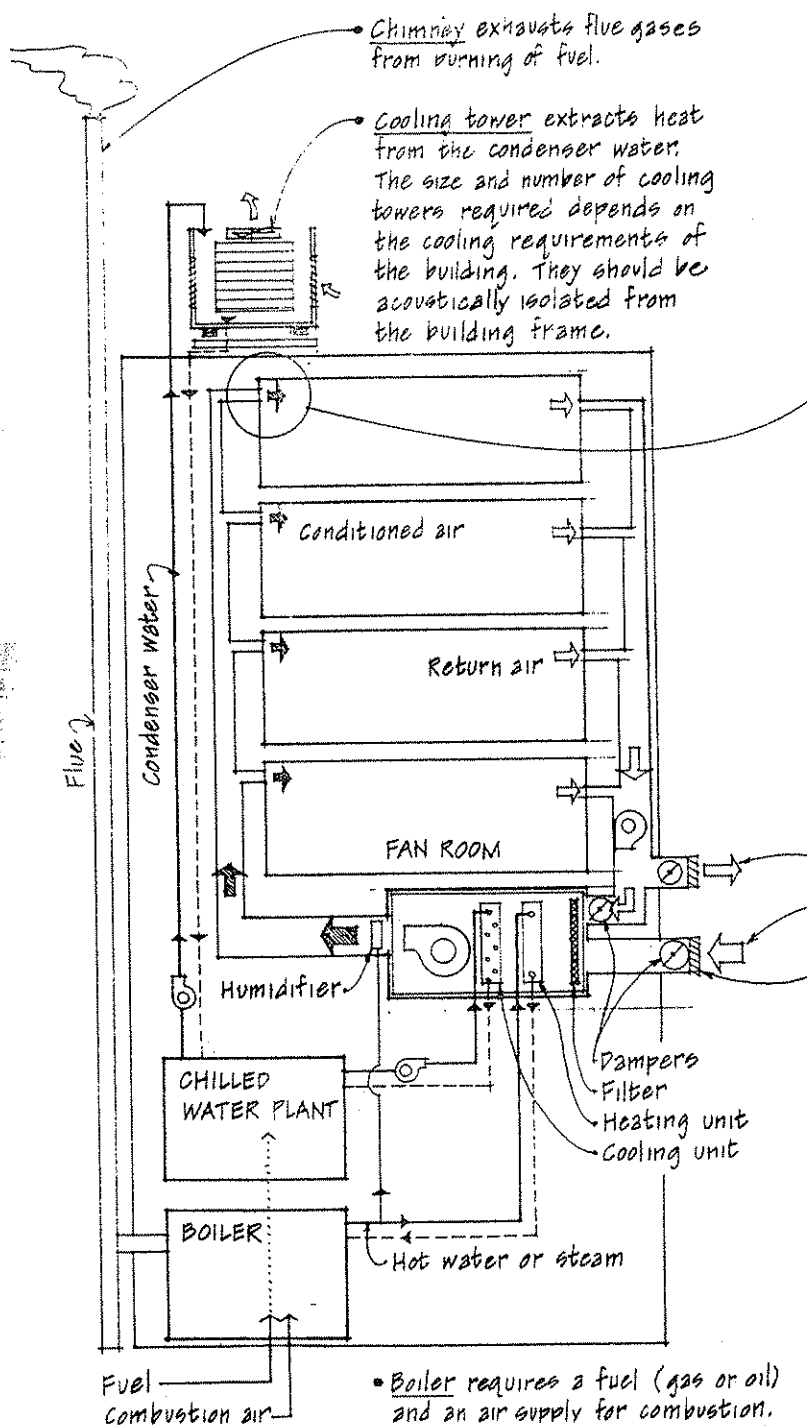
AIR TEMPERATURE AND AIR MOTION (V)

- The cooler the moving air stream is, relative to the room air temperature, the less velocity it should have.
- Air velocity should range between 10 and 50 feet per minute (FPM).
- Higher velocities can cause drafty conditions.
- Air motion is especially helpful for cooling by evaporation in hot, humid weather.



Air temperature requirements are also affected by the age group of the building's occupants, the weight and color of the clothing they wear, and the level of their activity.

II.4 AIR-CONDITIONING SYSTEMS



Air-conditioning systems do not simply provide summer cooling. They also control the indoor air temperature throughout the year, regulate humidity, provide fresh air for ventilation, filter the air, and distribute the conditioned air.

Heating and cooling energy in central air-conditioning systems can be distributed by air, water, or a combination of both. See II.5 and II.6.

Fan room contains the air handling equipment in large buildings. A single fan room should be located to minimize the distance conditioned air must travel to the farthest air-conditioned space. Individual fan rooms can also be located on each floor of a building.

Exhaust air

Fresh air

The louvers for centralized fan rooms can be large and conspicuous, and can therefore become significant elements in the design of a building's facade. Fresh air intakes and exhaust air louvers should be located on different walls or be separated by at least 10'.

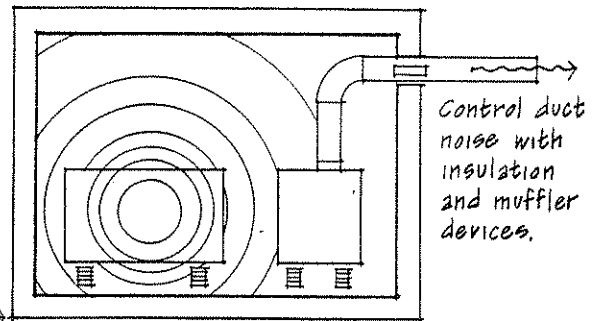
Boiler requires a fuel (gas or oil) and an air supply for combustion. Oil-fired boilers also need an on-site storage tank. Electric boilers, which may be feasible if electricity costs are low, eliminate the need for combustion air and a chimney.

If hot water or steam can be supplied by an off-site plant, a boiler is not required.

Chilled water plant may be powered by electricity, steam, or gas. It delivers chilled water to the air handling unit, and pumps condenser water to the cooling tower for the disposal of heat.

Factors to consider in the selection, design, and installation of an air-conditioning system include:

- Performance, efficiency, and both the initial and life costs of the system.
- Fuel and power sources required and the means for their delivery and storage.
- Flexibility of the system to service different zones of a building, which may have different demands because of use or site orientation.
- Noise and vibration controls required.
- Space requirements for the mechanical equipment and the distribution system.



Isolate noise and vibration:

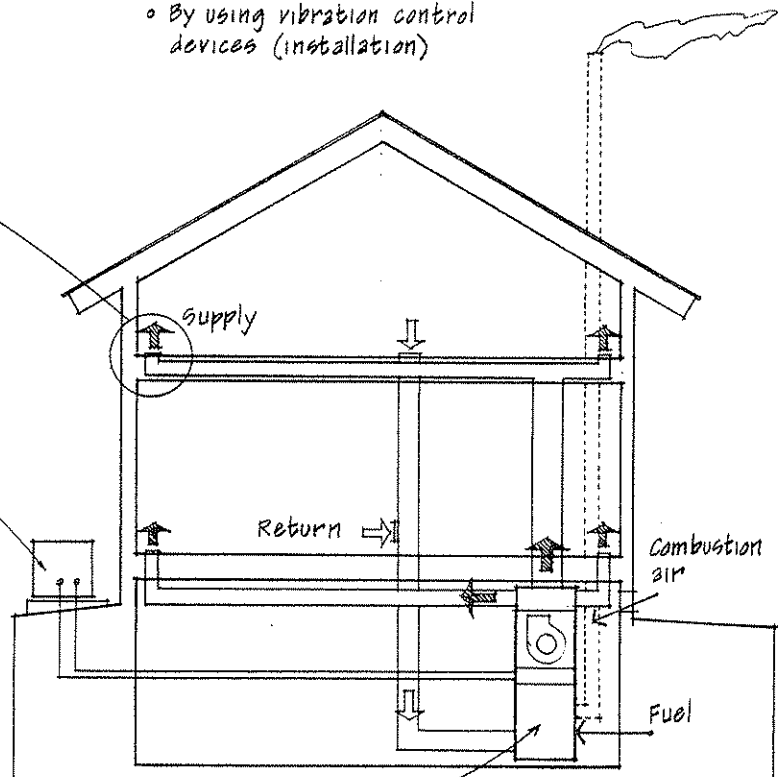
- By distance (location)
- With mass (enclosure)
- By using vibration control devices (installation)

In small buildings, heating energy may be supplied by forced air, hot water, or electric heating systems.

Cooling may be provided in a forced air system by an outdoor compressor and condensing unit. This unit supplies cold refrigerant to evaporator coils in the main supply ductwork.

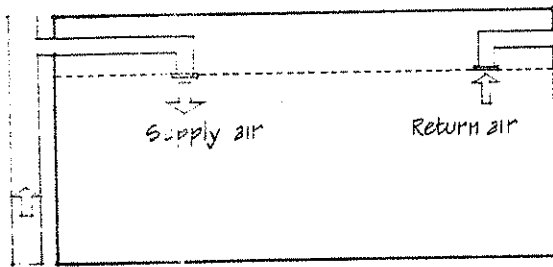
A forced air system can also incorporate filtering, humidifying, and dehumidifying devices into the installation.

Fresh air ventilation is usually provided by natural means.

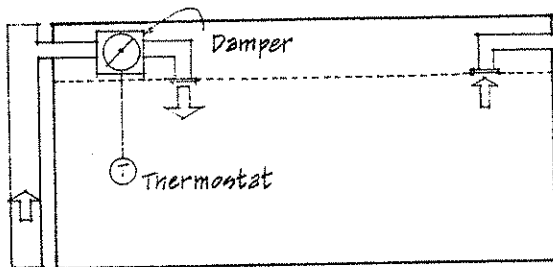


Furnace or boiler may be powered by gas, oil, or electricity. Oil furnaces require a fuel storage tank. Electric furnaces do not require combustion air or a chimney.

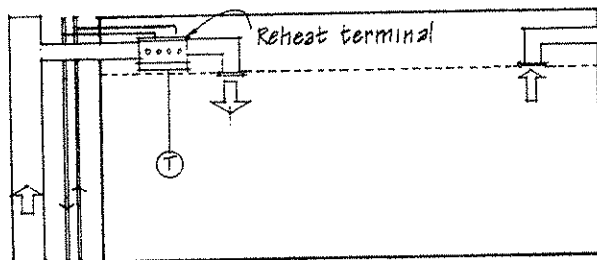
11.6 TYPES OF DISTRIBUTION SYSTEMS



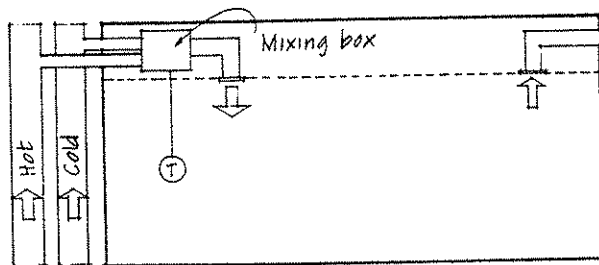
SINGLE ZONE SYSTEM



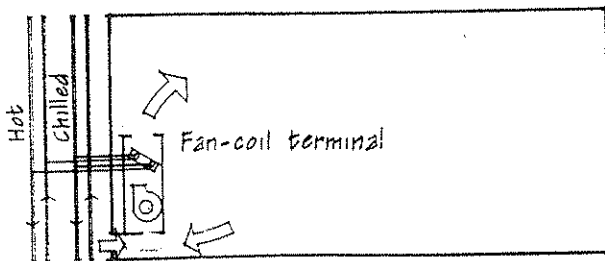
VARIABLE AIR FLOW SYSTEM



TERMINAL REHEAT SYSTEM



DOUBLE DUCT SYSTEM



ALL-WATER SYSTEM

ALL-AIR SYSTEMS

Single duct systems:

In a single zone system, conditioned air is delivered at a constant temperature through a low velocity duct system to the served spaces.

The variable air flow system uses dampers at the terminal outlets to control the air flow according to the requirements of each space.

The terminal reheat system is more flexible since it supplies air at about 55°F (12°C) to terminals equipped with hot water reheat coils to compensate for changing space requirements.

Double duct systems:

Separate duct systems deliver warm air and cool air to terminal mixing units which contain thermostatically controlled dampers. The mixing units may serve individual spaces or a number of zones.

This is usually a high-velocity system to reduce duct sizes and installation space.

ALL-WATER SYSTEMS

Pipes, which require less installation space than air ducts, deliver hot and/or chilled water to fan-coil units in the served spaces.

The fan-coil units draw a mixture of outdoor and room air over the coils of heated or chilled water and then back into the space.

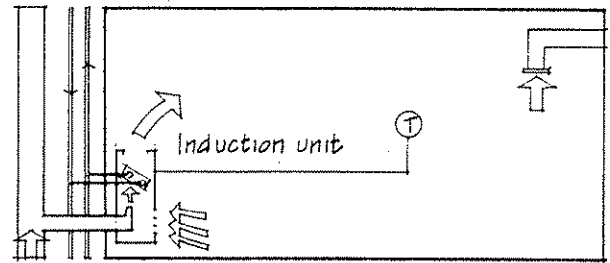
In a 2-pipe system, one pipe supplies either hot or chilled water to each fan-coil unit and the other returns it.

In a 4-pipe system, two separate piping circuits – one for hot water and one for chilled water – are used to provide simultaneous heating and cooling to different zones of a building.

Ventilation is provided through wall openings, by infiltration, or by a separate duct system.

AIR AND WATER SYSTEMS

High velocity ducts deliver conditioned primary air to induction units in the served spaces. The primary air induces room air to mix with it and pass over coils that are heated or cooled by a secondary water system.



AIR AND WATER SYSTEM

PACKAGED AIR-CONDITIONING UNITS

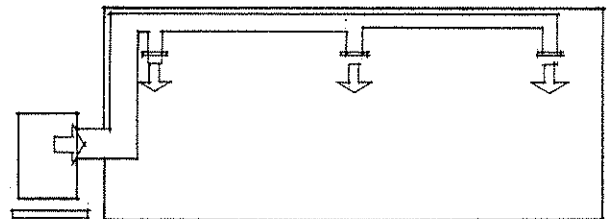
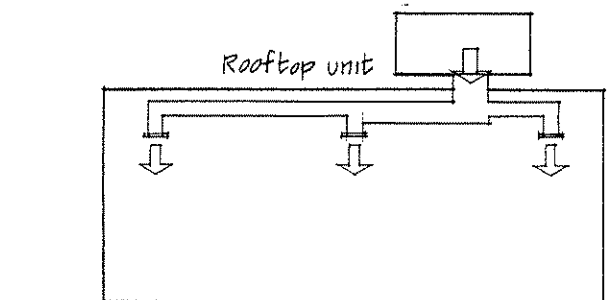
Packaged air-conditioning units are self-contained systems which can serve either single- or multizone configurations. They may be located on the roof or on a pad alongside the building. Small units can be installed in window or wall openings.

Cooling is provided by condensing units which require an outdoor location.

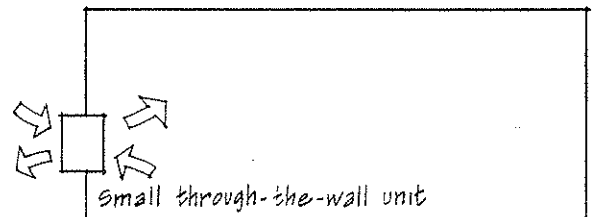
Heating is provided by a gas or oil furnace, electric resistance heaters, or a heat pump.

Heat pumps are electrically powered heating and cooling units. For cooling, the normal refrigeration cycle is used to absorb and transfer excess heat to the outdoors. For heating, heat energy is drawn from the outdoor air by reversing the cooling cycle and switching the heat exchange functions of the condenser and evaporator.

Heat pumps are most efficient in moderate climates where heating and cooling loads are almost equal. In freezing temperatures, a heat pump requires an electric resistance heater to keep the outdoor coils from freezing.



Through-the-wall unit

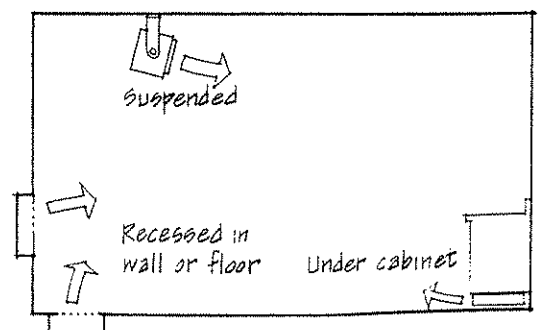


PACKAGED SYSTEMS

ELECTRIC HEATING

Electric resistance heating elements may be incorporated into baseboard convection units or into fan-forced unit heaters. These small unit heaters may be recessed in the floor or wall, be suspended from the ceiling, or be located under a cabinet.

Electric resistance heating cables can also be embedded in ceiling panels or floor slabs to provide radiant heating. See 11.12.



ELECTRIC RESISTANCE HEATERS

11.8 DISTRIBUTION PATTERNS

Factors to consider in the location of heating, cooling, and air-conditioning equipment include:

- Power, fuel, air, and water requirements; some equipment requires direct access to the outdoors.
- Access required for service and maintenance.
- Construction requirements for the enclosure of the mechanical plant, for fire resistance, and for noise and vibration control.
- Structural requirements imposed by the weight of the equipment.
- Type and layout of the distribution system used for the heating and cooling media.
- Type of installation - concealed within the building's construction or exposed to view.

A building's mechanical equipment can occupy a significant amount of space within the building volume. Some pieces of equipment also require space or a domain for access, service, and maintenance. If this machinery takes up 10% to 15% of a building's area, as is often the case, then it becomes necessary to consider the implications of the equipment's placement within the building.

A building's machinery and equipment may be located:

WITHIN A SPACE

Central locations are ideal for short runs and efficient distribution patterns. The equipment enclosure may serve to define or qualify a number of related spatial zones.

DIRECTLY ADJACENT TO A SPACE

The equipment enclosures may serve as wall or barrier elements.

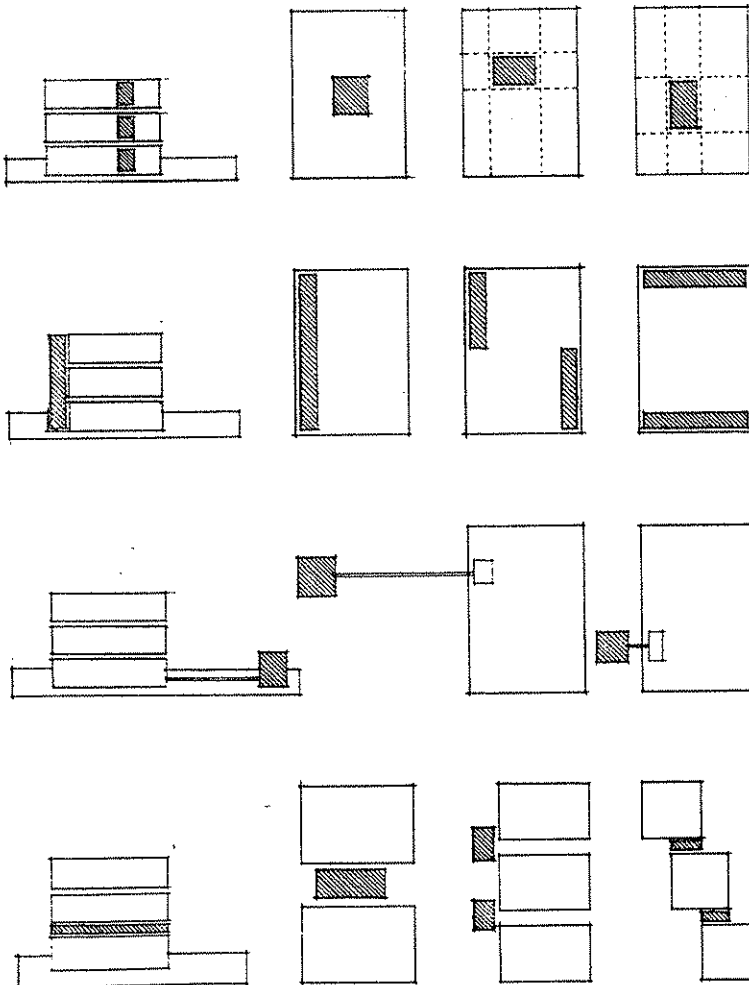
OUTSIDE THE SPACE

The equipment may be isolated for better noise control or for easier access to utilities and service.

BETWEEN SPACES

The equipment may be dispersed to better serve spaces or zones that have different demands and load requirements.

Note that the above relationships also apply to the location of plumbing and electrical equipment.



The air-conditioning equipment may be centralized in one location or dispersed throughout a building. Some equipment requires both indoor and outdoor components; others may be self-contained units which can be located on the roof or on exterior walls. The distribution pattern of the ducts or piping used to deliver the heating or cooling medium to the served spaces is determined by:

- The locations of the heating, cooling, and air-conditioning equipment
- The arrangement of the served spaces.

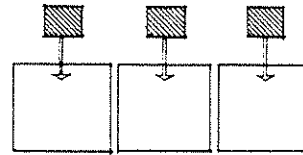
Air duct systems require more space than either pipes carrying hot or chilled water or wiring for electric resistance heating. For this reason, ductwork must be carefully laid out to be integrated with a building's structure and spaces, as well as with its plumbing and electrical systems. If the ductwork is to be left exposed, it becomes even more important that the layout have a visually coherent order and be coordinated with the physical elements of the space (e.g., structural elements, lighting fixtures, surface patterns).

Vertical duct runs are housed in mechanical shafts while horizontal runs may be under ground slabs, in basement or crawl spaces, or within floor or roof construction assemblies.

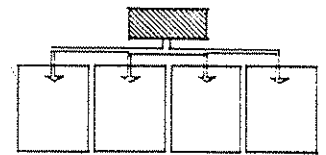
Horizontal distribution patterns may be classified as radial, perimeter, or lateral in nature.

- Radial patterns minimize the length of horizontal runs. They can be used in clear spaces which are free of obstacles.
- Perimeter loop patterns are effective against heat losses and gains that occur along the perimeter of a building. They are used in conjunction with concrete ground slabs.
- Lateral patterns require the longest horizontal runs, but offer a wide, uniform, and flexible system of distribution. Exposed ductwork systems usually utilize a lateral pattern layout.

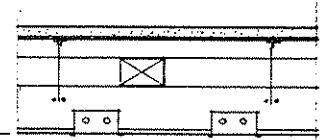
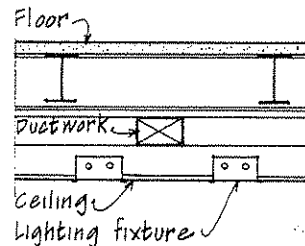
To minimize friction loss, ductwork should have short, direct runs with a minimum of turns and offsets. In addition, ducts should be insulated against heat loss or gain and sound transmission.



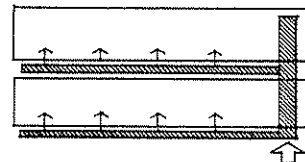
Local systems are economical to install, require short distribution runs, and allow spaces to have individual temperature control.



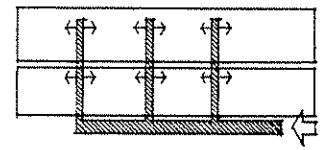
Central systems are generally more energy-efficient, easier to service, and offer better control of air quality.



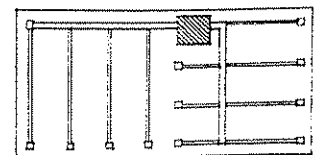
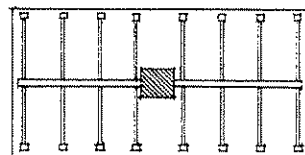
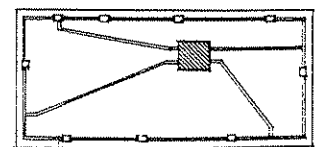
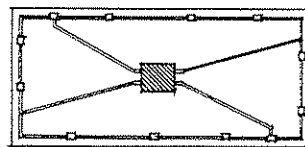
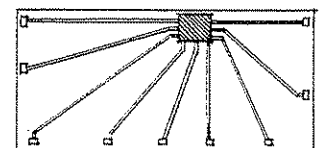
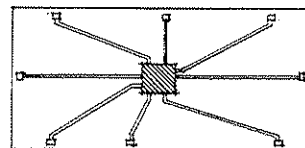
Careful integration of structural, mechanical, and electrical systems can conserve space.



Main vertical feeder uses less floor area but increases building height.

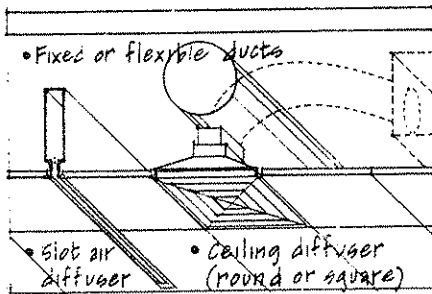


Main horizontal feeder uses more floor area but decreases building height.

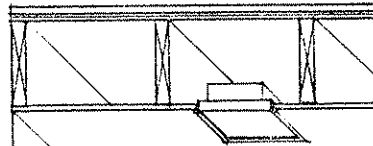


11.10 HEATING AND COOLING OUTLETS

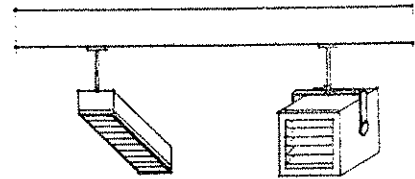
The location of heating and cooling outlets depends on the size and proportions of the space, the areas of heat loss or gain, the wall, floor and ceiling construction, and the occupants' activity patterns. The type of outlet used depends on its placement within the space, its heating or cooling capacity, and its dimensions and appearance. Below are illustrated various types of outlets according to location and the heating or cooling medium used.



- Fixed or flexible ducts
- Slot air diffuser
- Ceiling diffuser (round or square)
- Require a suspended ceiling
- Supplied by low-velocity ductwork
- May be a part of an integrated, modular ceiling system

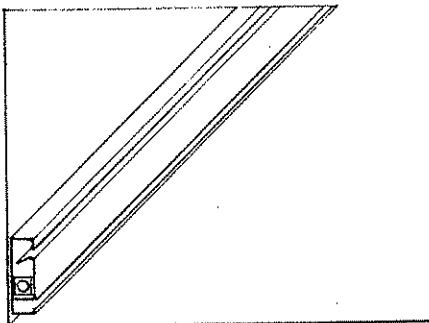


- Electric ceiling heater
- Convection or forced air heating
- May be combined with a light fixture and/or an exhaust fan
- See 11.12 for radiant ceiling panels.

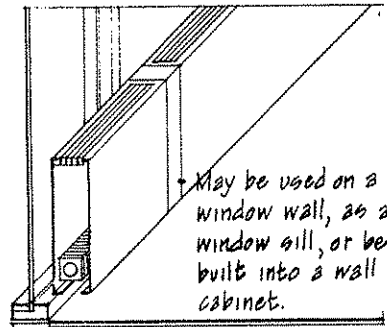


- Infrared heater
- Radiant heating
- Can be used in protected outdoor locations
- Space heater
- Electric or gas
- Forced air heating

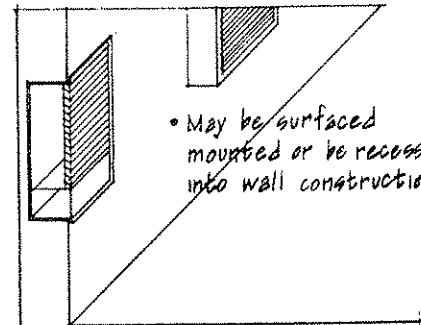
CEILING LOCATIONS



- Baseboard unit
- Fin tube or fan coil unit, or electric resistance heater

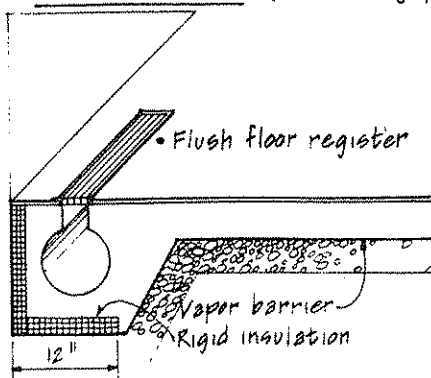


- Mullion or wall-mounted unit
- Fin tube or fan coil unit, or electric resistance heater

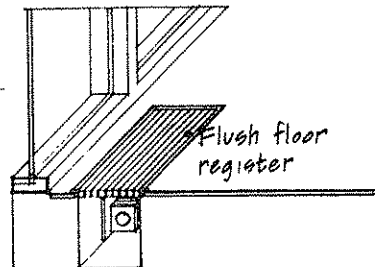


- May be surfaced mounted or be recessed into wall construction
- Electric wall heaters
- Heat by radiation, convection, or forced air

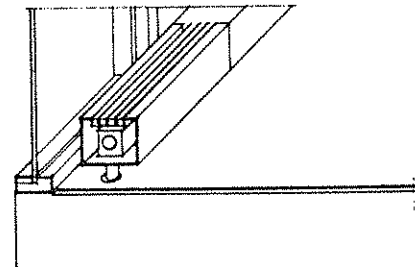
WALL LOCATIONS (See facing page for air grilles and diffusers.)



- Flush floor register
- Perimeter loop duct in concrete ground slab (See 3.20)
- Vapor barrier
- Rigid insulation



- Underfloor convector unit
- Fin tube or fan coil unit, or electric resistance heater
- Used along window walls

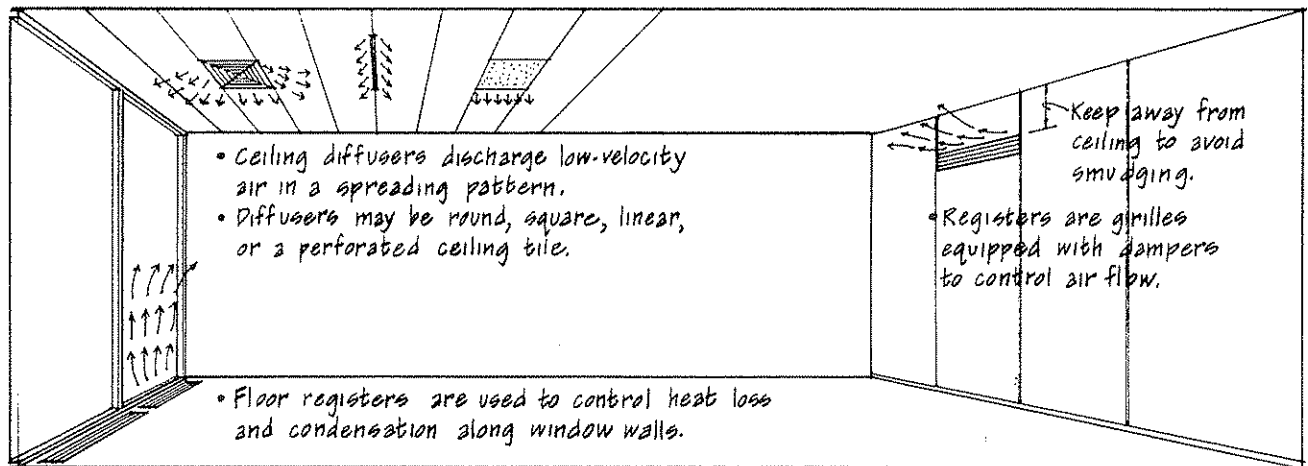


- Free-standing fin tube unit
- Low profile units may be used along window walls

FLOOR LOCATIONS

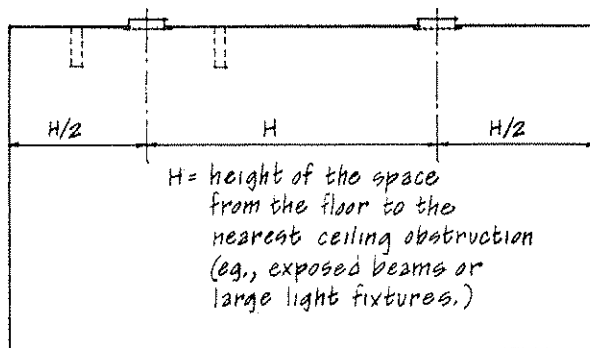
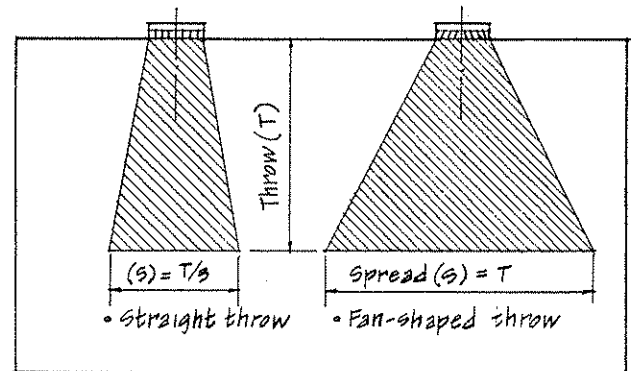
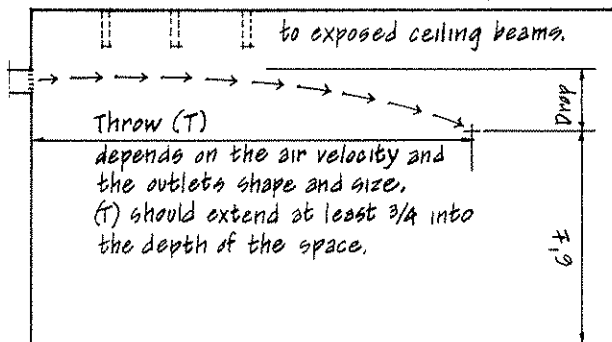
AIR SUPPLY GRILLES AND DIFFUSERS

Air for heating, cooling, and ventilating is supplied through grilles, registers, and diffusers. They should be evaluated in terms of their air flow capacity and velocity, pressure drop, noise factor, and appearance.

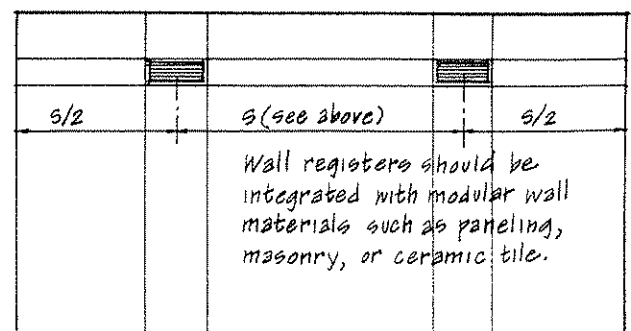


Air supply outlets should be located to distribute warm or cool air to the occupied areas of a space comfortably, without noticeable drafts, and without stratification. The throw distance and spread or diffusion pattern of the supply outlet should be carefully considered along with any obstructions that might interfere with the air distribution.

- Air flow should be parallel to exposed ceiling beams.



SPACING OF CEILING DIFFUSERS



SPACING OF WALL REGISTERS

11.12 RADIANT PANEL HEATING

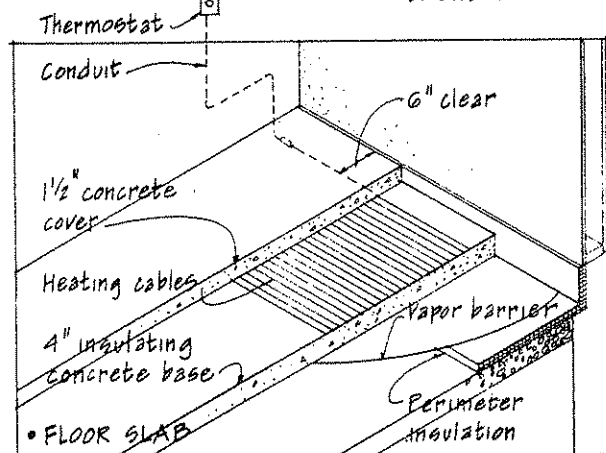
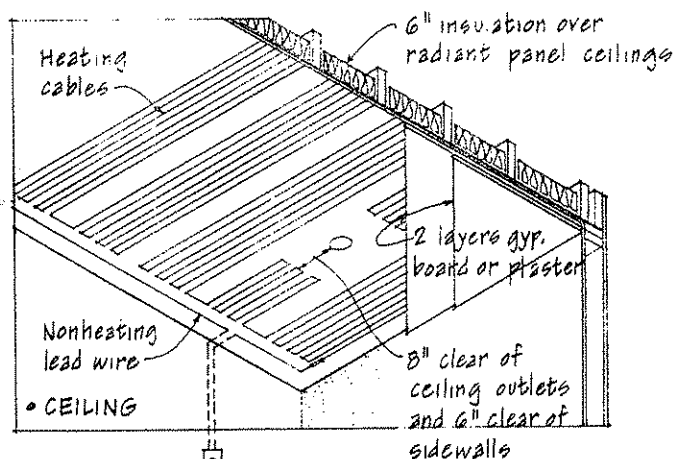
Radiant panel heating systems utilize heated ceilings, floors, and sometimes walls, as radiating surfaces. The heat source may be pipes carrying hot water or electric resistance heating cables embedded within the ceiling, floor, or wall construction.

Radiant heat travels in a direct path.

- It cannot go around corners and may therefore be obstructed by physical elements within the space such as furniture.
- It cannot counteract cold downdrafts along exterior glass areas.
- It is not affected by air motion.

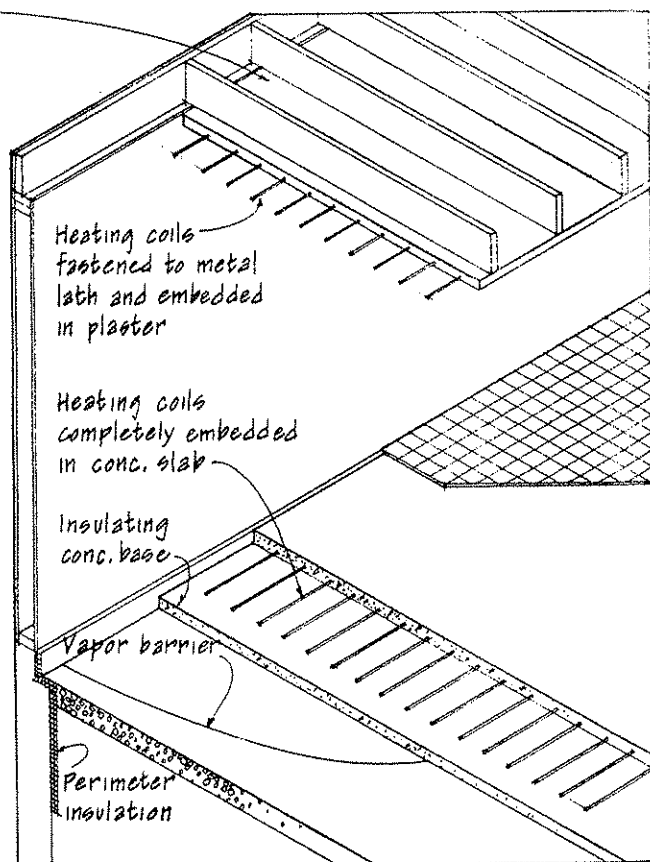
Because radiant panel heating systems cannot respond quickly to changing temperature demands, they may be supplemented with perimeter convector units. For complete air-conditioning, separate ventilating, humidity control, and cooling systems are required.

Floor installations are effective warming concrete slabs. In general, however, ceiling installations are preferred because the ceiling construction has less thermal capacity and thus faster heat response. Ceiling panels can also be heated to a higher surface temperature than floor slabs.



ELECTRIC RADIANT PANEL HEATING

Preassembled radiant heating panels are commercially available. They may be used with modular, suspended ceiling systems or to heat specific areas of a space.



HOT WATER RADIANT PANEL HEATING

In both electric and hot water systems, the installations are completely concealed except for thermostats or balancing valves.

WATER SUPPLY

T1.15

Water is utilized in a building in the following ways:

- Consumed by drinking, cooking, washing etc. ... (must be potable)
- Circulated by heating and cooling systems..... (should be soft or neutral)
- Stored by fire protection systems..... (no special requirements)
- Controlled to maintain desirable humidity levels

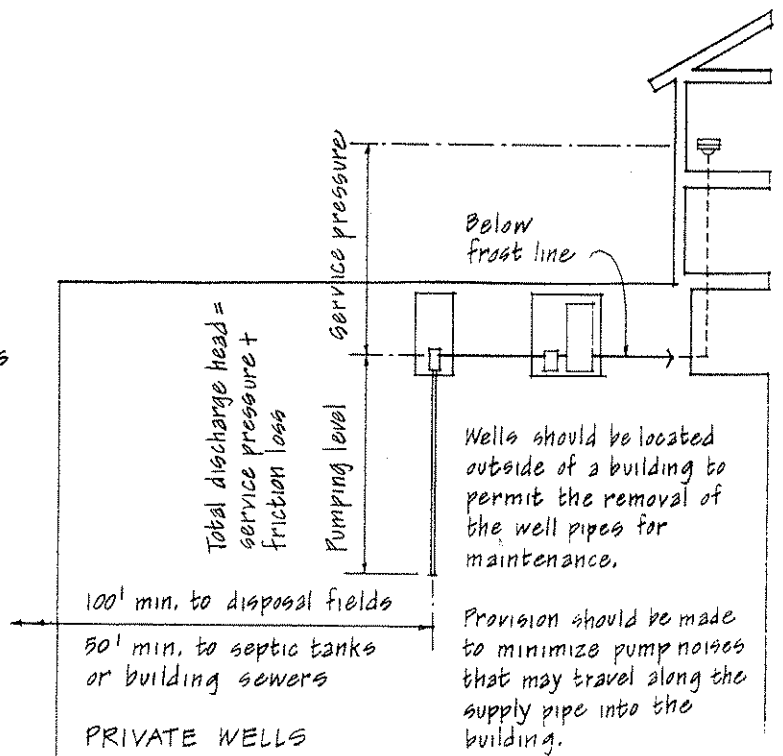
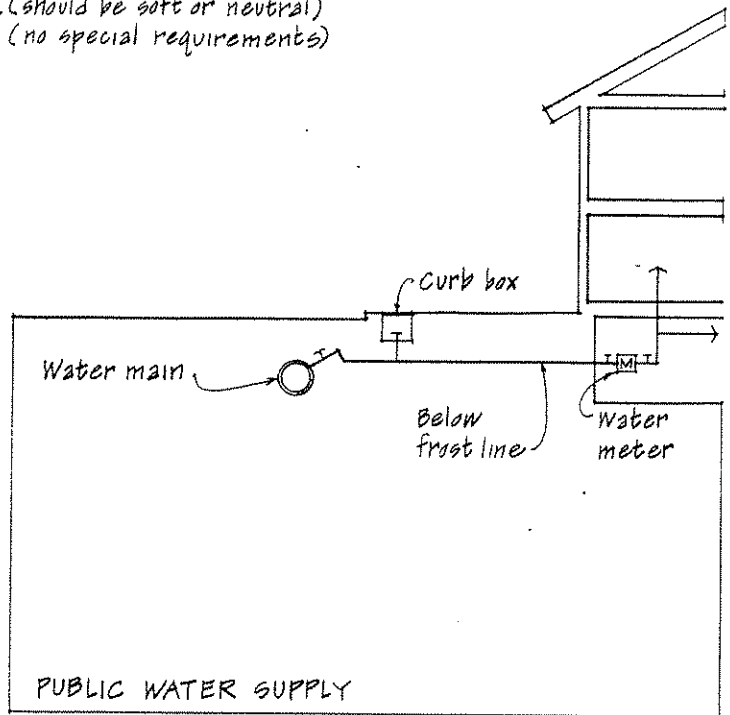
Water must be supplied to a building in the correct quantity, and at the proper flow rate, pressure and temperature, to satisfy the above requirements. For human consumption, water must be palatable and free of harmful bacteria. To avoid the clogging or corrosion of pipes and equipment, water may have to be treated for hardness or excessive acidity.

If water is supplied by a municipal or public system, there can be no direct control over the quantity or quality of water supplied until it reaches the building site. If a public water system is not available, then either rainwater storage tanks or drilled wells are required.

Well water, if the source is deep enough, is usually pure, cool, and free of discoloration and taste or odor problems. Factors to consider in the selection of a well location include:

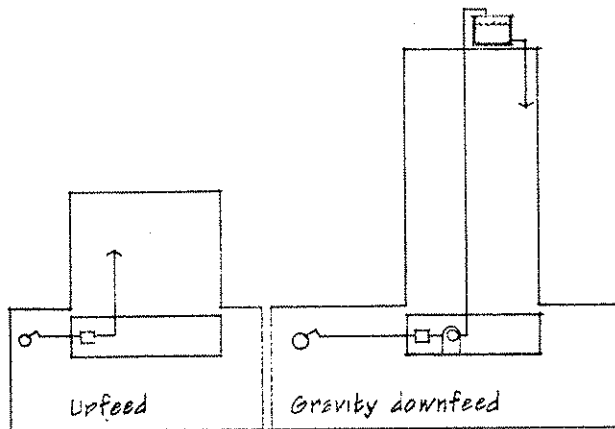
- Quality of the water to be supplied; should be checked by the local health department.
- Amount of water that can be supplied by the source.
- Required depth and cost of the well.
- Proximity of the well to areas containing pollutants.

Water supply systems operate under pressure. The service pressure of a water supply system must be great enough to absorb pressure losses due to vertical travel and friction as the water flows through pipes and fittings, and still satisfy the pressure requirement of each plumbing fixture. Public water systems usually supply water at about 50 psi. This pressure is the approximate upper limit for most private well systems.



Check applicable codes that govern well installations.

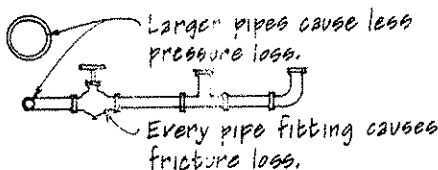
11.14 WATER SUPPLY SYSTEMS



If water is supplied at 50 psi, upfeed distribution is feasible for lowrise buildings up to 6 stories in height. For taller buildings, or where the water service pressure is insufficient to maintain adequate fixture service, water is pumped up to an elevated or rooftop storage tank for gravity downfeed. Part of this water is often used as a reserve system for fire protection systems.

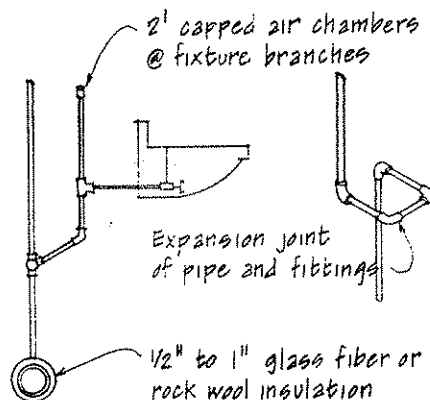
Hot water is supplied by gas-fired or electric heaters and circulated in tall buildings by the natural rising action of hot water. In long, low buildings, pumps are required for hot water circulation and distribution. Hot water storage tanks may be required for large installations and widespread fixture groupings. For safety, pressure relief valves are required for all water heaters.

- + Fixture pressure requirements
 - + Pressure loss due to vertical lift
 - + Pressure loss due to friction in pipe runs
-
- = Water service pressure



There must be sufficient pressure at each fixture to ensure their satisfactory operation. Fixture pressure requirements vary from 5 to 30 psi. Too much pressure is as undesirable as insufficient pressure. Water supply pipes are therefore sized to use up the differential between the service pressure (allowing for the pressure loss due to vertical lift) and the pressure requirement for each fixture.

The amount of pressure loss due to friction depends on the size of the supply pipe, the actual distance of the water flow, and the number of fittings (valves, tees, elbows) through which the water passes.

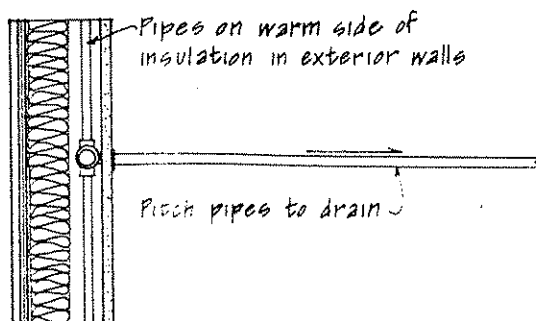


Pipe supports should be spaced to carry the weight of the pipe as well as the water being distributed through it.

- Vertically, at least every story
- Horizontally, every 6' to 10'

Adjustable hangers can be used to ensure proper pitch along horizontal runs for drainage purposes.

Water hammer is a noise that can occur when water is shut off abruptly. To absorb this shock, air chambers or manufactured shock absorbers are used at fixture branches. In tall buildings, special joints are required to allow for the expansion of long pipe runs carrying hot water.



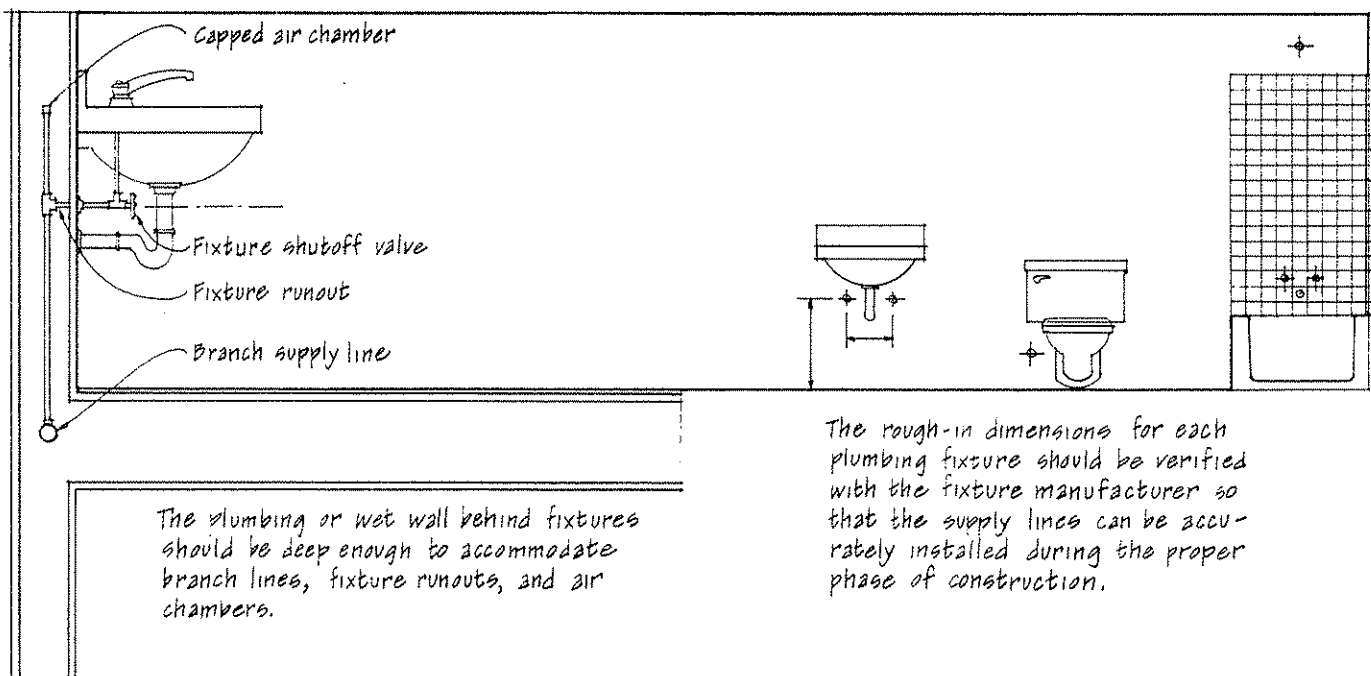
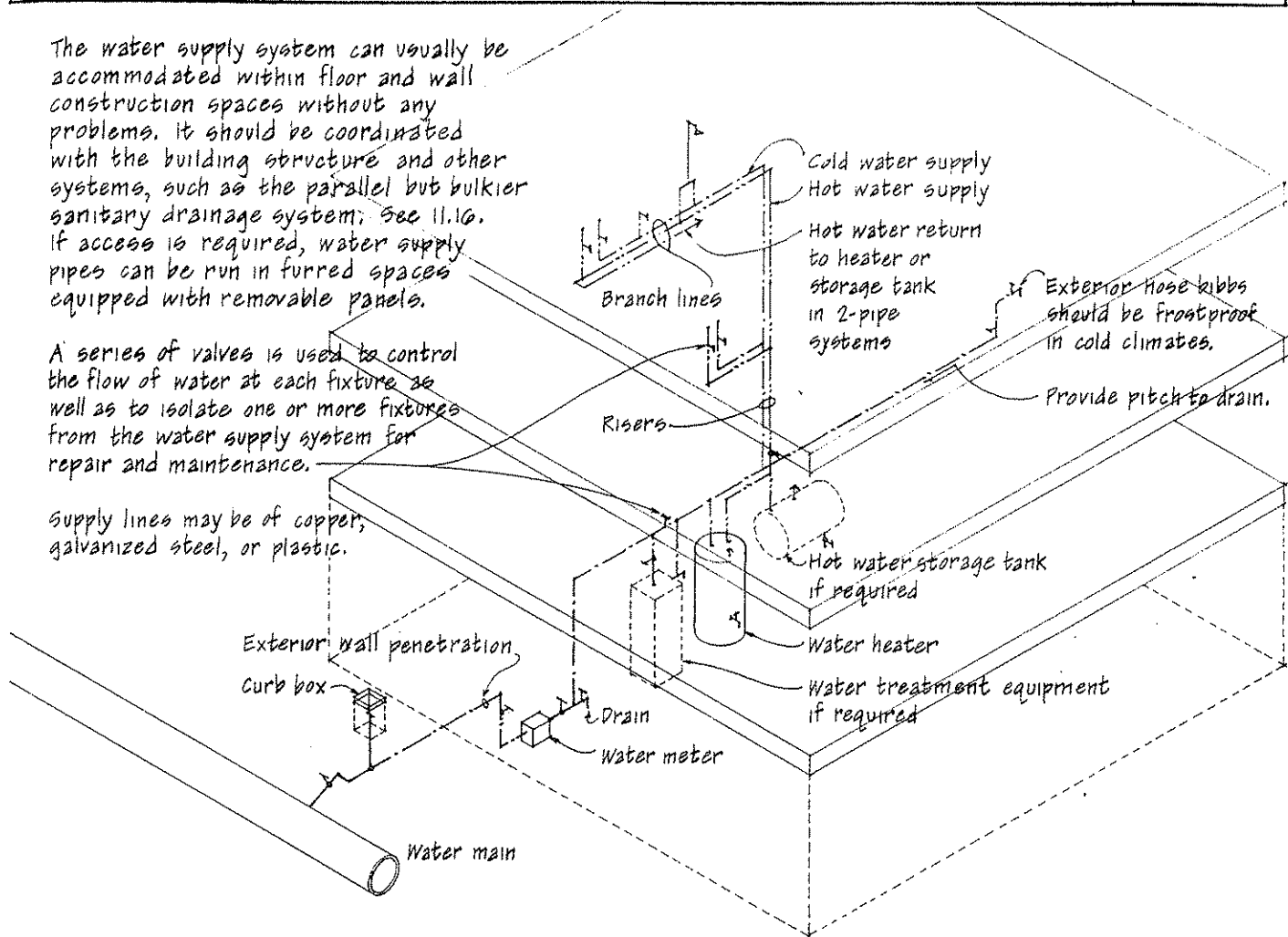
Cold water pipes should be insulated and covered with a vapor barrier to prevent surface condensation and heat flow into the water from the warmer surrounding air. Hot water pipes should be insulated against heat loss and should be no closer than 6" to parallel cold water pipes.

In very cold climates, water pipes in exterior walls and unheated buildings can freeze and rupture. Provision should be made for their drainage to a low point in the system where a drainage faucet is located.

The water supply system can usually be accommodated within floor and wall construction spaces without any problems. It should be coordinated with the building structure and other systems, such as the parallel but bulkier sanitary drainage system; See 11.16. If access is required, water supply pipes can be run in furred spaces equipped with removable panels.

A series of valves is used to control the flow of water at each fixture as well as to isolate one or more fixtures from the water supply system for repair and maintenance.

Supply lines may be of copper, galvanized steel, or plastic.



11.16 SANITARY DRAINAGE SYSTEMS

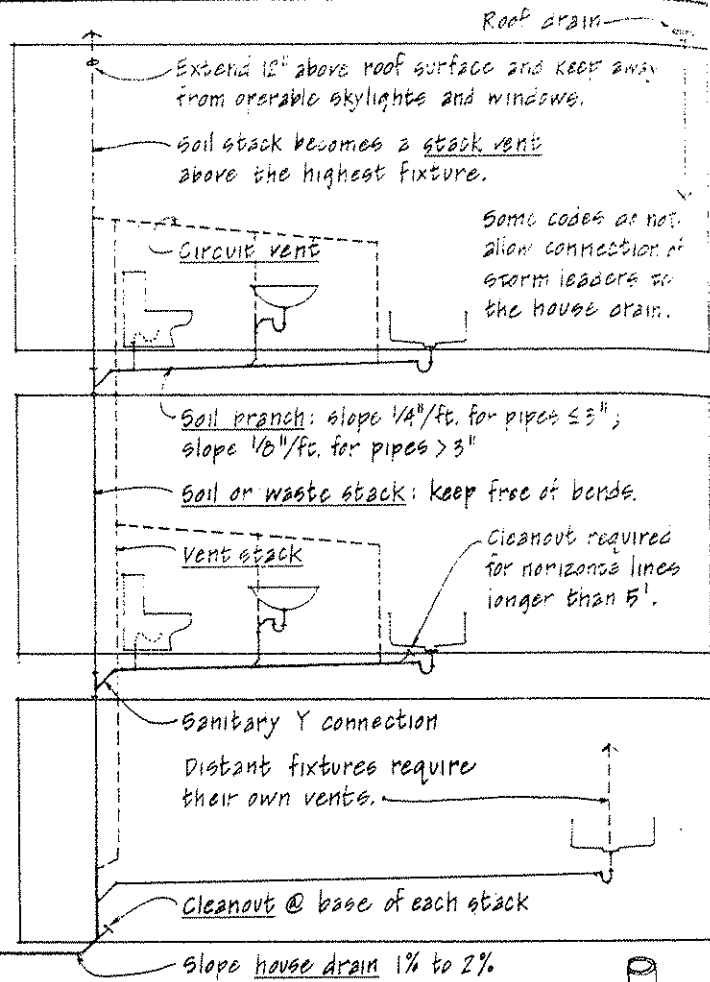
The water supply system terminates at each plumbing fixture. After water has been drawn and used, it enters the sanitary drainage system. The primary objective of this drainage system is to dispose of fluid waste and organic matter as quickly as possible.

Since a sanitary drainage system relies on gravity for its discharge, its pipes are much larger than the water supply lines which are under pressure. Drainage lines are sized according to their location in the system and the total number and type of fixtures served. Always consult the local plumbing code for pipe sizing, pipe materials, and restrictions on the length and slope of horizontal runs and on the types and number of turns allowed.

A sump pump is required for fixtures located below the street sewer.

Building sewer line
Sanitary street sewer

House trap if required by code



Vents

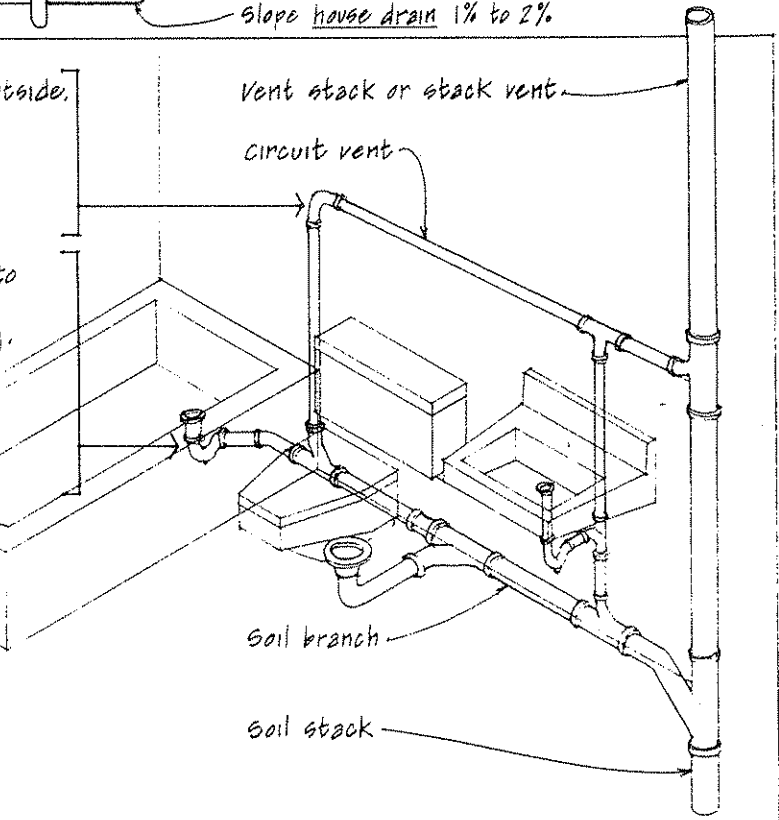
- permit septic gases to escape to the outside.
- admit fresh air into the system.
- help prevent water seals in traps from being siphoned out or gases to bubble through under pressure.

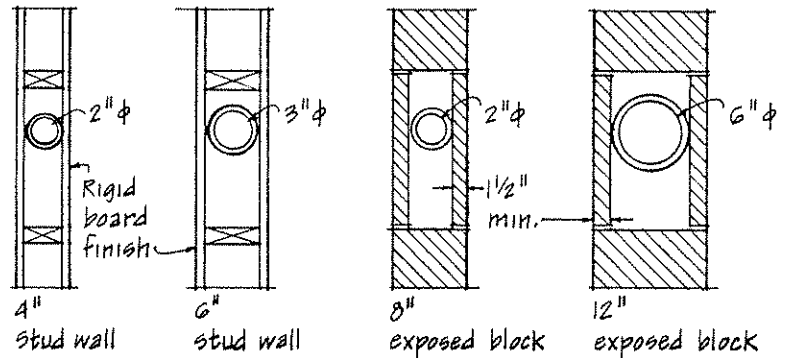
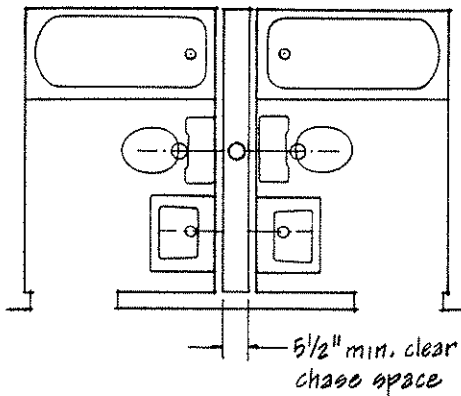
Traps

- utilize a portion of the waste water to act as a seal and prevent sewer gases from entering the interior of a building.
- are required for every fixture.

Fixtures should have sufficient flow to periodically clean out their traps and prevent sediment from collecting.

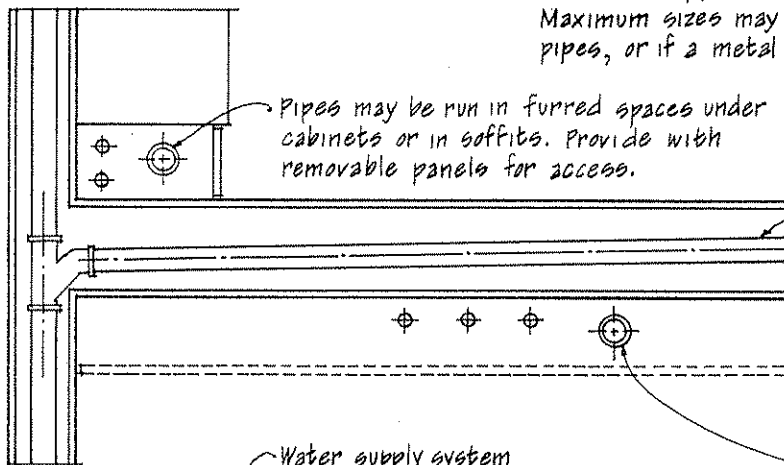
The layout of the sanitary drainage system should be as direct and straightforward as possible to prevent the deposit of solids and clogging. Cleanouts should be located to allow pipes to easily be cleaned if they do clog.





MAXIMUM PIPE SIZES IN VARIOUS PARTITIONS

The above applies to extra heavy cast iron bell and spigot pipe. Maximum sizes may be slightly larger for no-hub or plastic pipes, or if a metal lath and plaster wall finish is used.

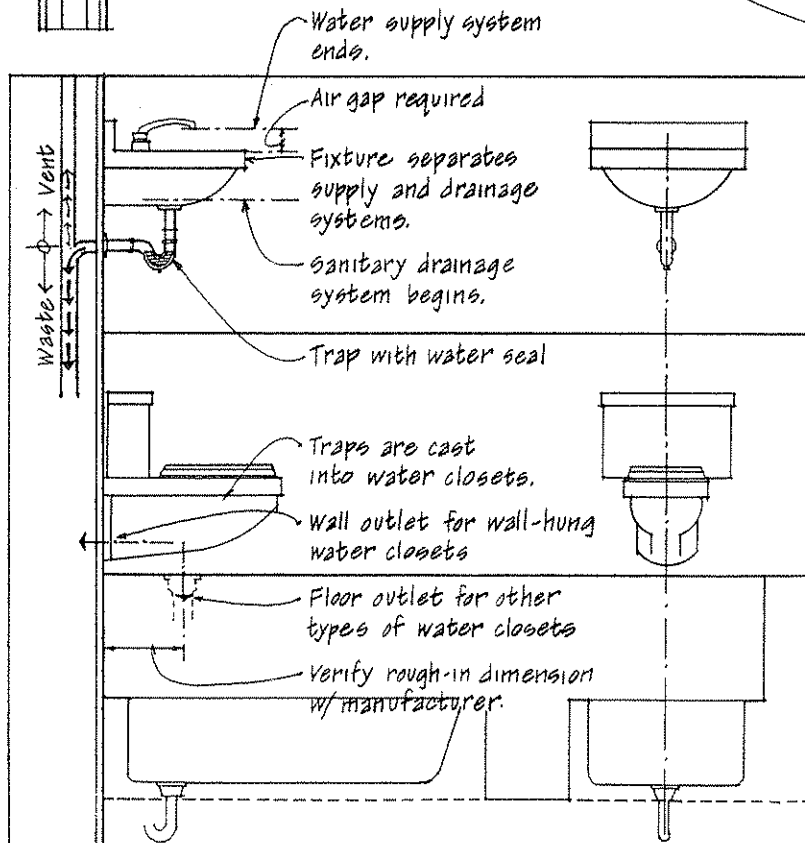


- Branch lines for water closets, urinals, slop sinks, and tubs are usually run within the floor system.

- Horizontal branch lines should slope 1/8"/ft. for pipes up to 3" φ, and 1/4"/ft. for pipes larger than 3" φ.

- Path of branch lines within a floor system should be coordinated with the floor framing members.

- Pipes may be run within a suspended ceiling space if structural or mechanical obstructions occur within the floor system.



- Drainage lines may be of cast iron (bell and spigot or no-hub type) or of plastic. Some codes also permit the use of galvanized wrought iron or steel.

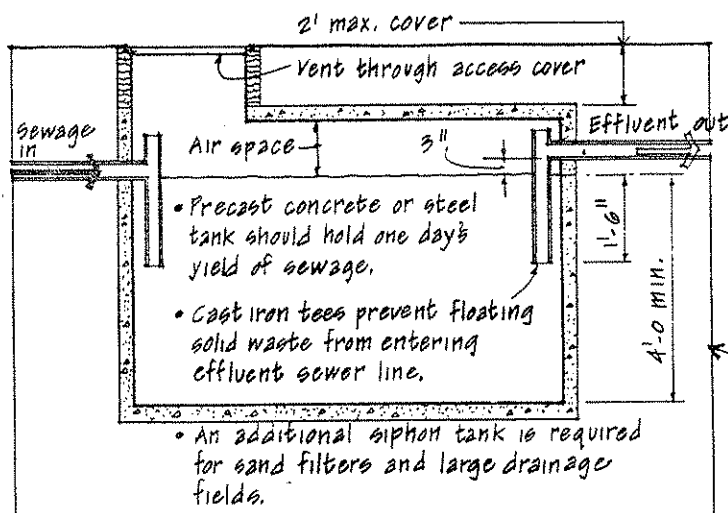
- Fixtures should be of a dense, smooth, nonabsorbent material, and be free of concealed fouling surfaces.

11.18 SEWAGE DISPOSAL SYSTEMS

A building's sewage wastes are usually deposited into a public sewage system for treatment and disposal. When this is not possible, a private sewage disposal system is required. Its type and size depends on the following:

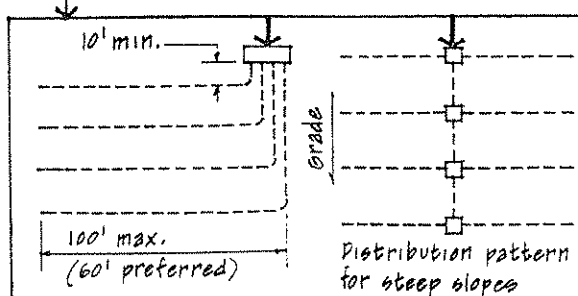
- Number of people served
- Type and permeability of the soil
- Site topography
- Elevation of the ground water table
- Proximity to wells and streams.

A private sewage disposal system always requires a septic tank.

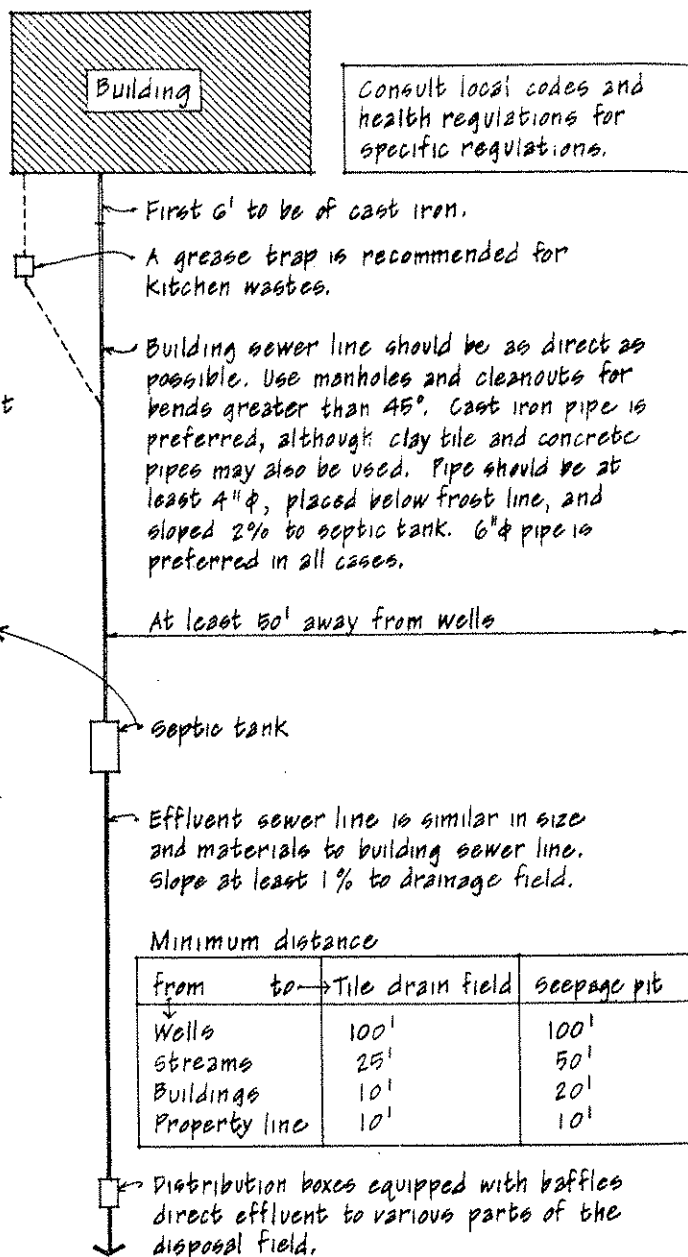


A septic tank is a holding container for sewage that allows bacteria action to break down solid waste matter into compact sludge and lets the liquid effluent, which is about 70% purified, flow into one of the following.

- ① Sand filter is used only where other systems are not feasible.
- ② Seepage pit is used when soil is absorbent and highest level of water table is at least 2' below bottom of pit.
- ③ Tile drain fields are placed on the sunny side of slopes, and not under drives or heavily planted areas.

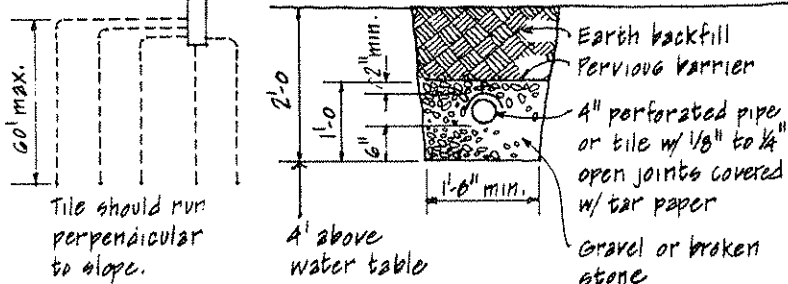


EXAMPLES OF TILE DRAIN FIELD PATTERNS



Minimum distance

From	to	Tile drain field	Seepage pit
Wells		100'	100'
streams		25'	50'
Buildings		10'	20'
Property line		10'	10'



SECTION THROUGH TILE DRAIN

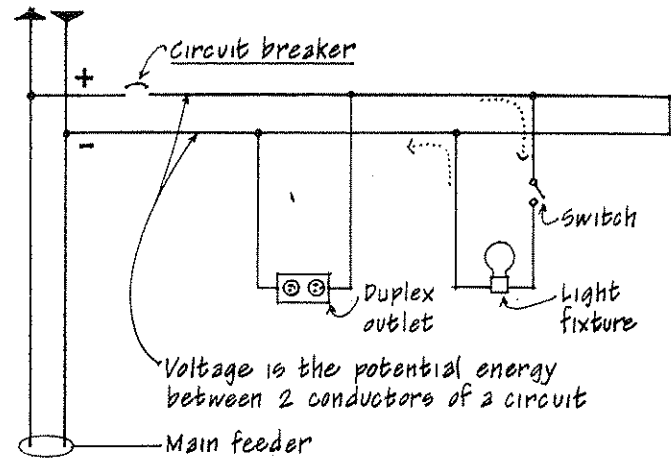
ELECTRIC POWER SUPPLY

The electrical system of a building supplies power for lighting, heating, and the operation of electrical equipment and appliances. This system must be installed according to code to operate safely, reliably, and efficiently.

Electrical energy flows through a conductor because of a difference in electrical charge between two points in a circuit. This potential energy is measured in volts. The actual amount of energy flow or current is measured in amperes. The power required to an electric current flowing is measured in watts. Power in watts equals the current in amperes times the pressure in volts. ($W = A \times V$)

Just as pressure is lost due to friction as water flows through pipes, the flow of electrical current is impeded by resistance, measured in ohms, as it travels through a conductor.

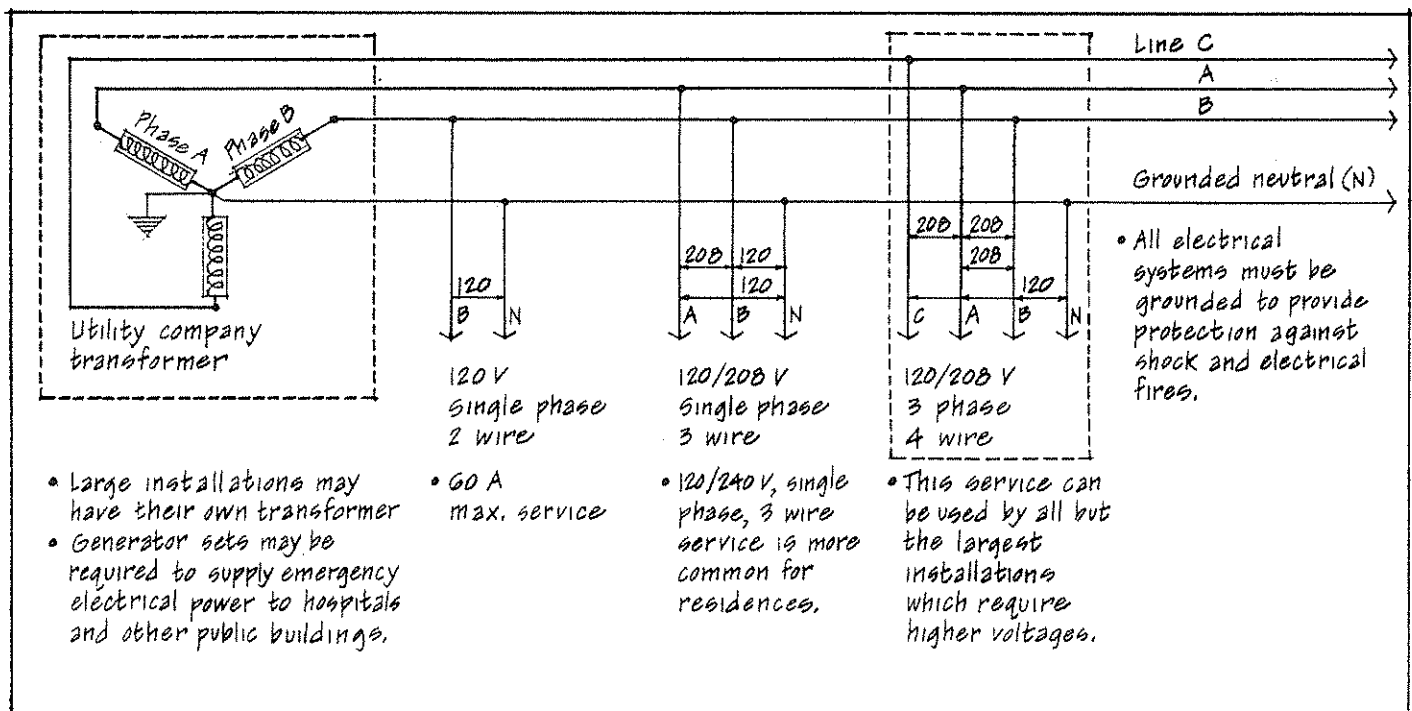
Power is supplied to a building by the electric utility company. The schematic diagram below illustrates several voltage systems that may be furnished by the public utility according to a building's load requirements. A large installation may use its own transformer to switch from a more economical, higher supply voltage to the service voltage.



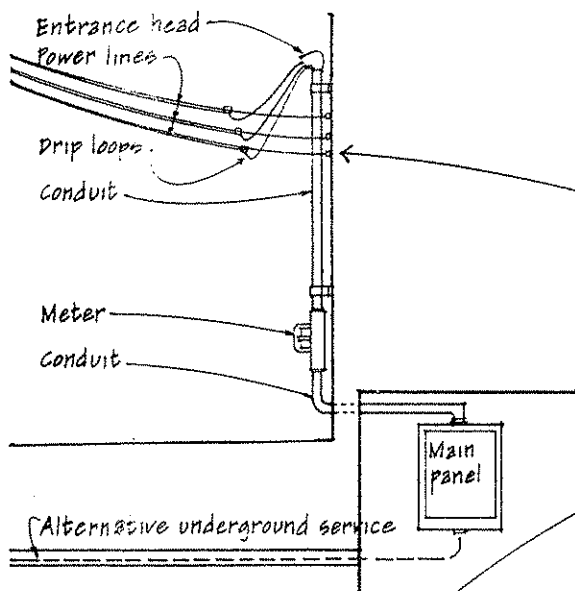
SCHEMATIC OF A BRANCH CIRCUIT

For electric current to flow, a circuit must be complete. Switches control flow by introducing breaks in the circuit until power is required.

All electrical equipment should meet the Underwriters' Laboratories (UL) standards. Consult local applicable codes for specific requirements in the design and installation of an electrical system.



11.20 ELECTRICAL SERVICE



The utility company should be notified of the estimated total electrical load requirements for a building during the planning phase to confirm service availability and to coordinate the location of the service connection and meter.

The service connection may be overhead or underground. Overhead service is less expensive, easily accessible for maintenance, and can carry high voltages over long runs.

- Underground service is more expensive but is used in high load density situations such as urban areas. The service cables are run in pipe conduit or raceways for protection and to allow for future replacement. Direct burial cable may be used for residential service connections.

The meter is always placed ahead of the service switch so that it cannot be disconnected. It is supplied by the public utility and should be easily accessible.

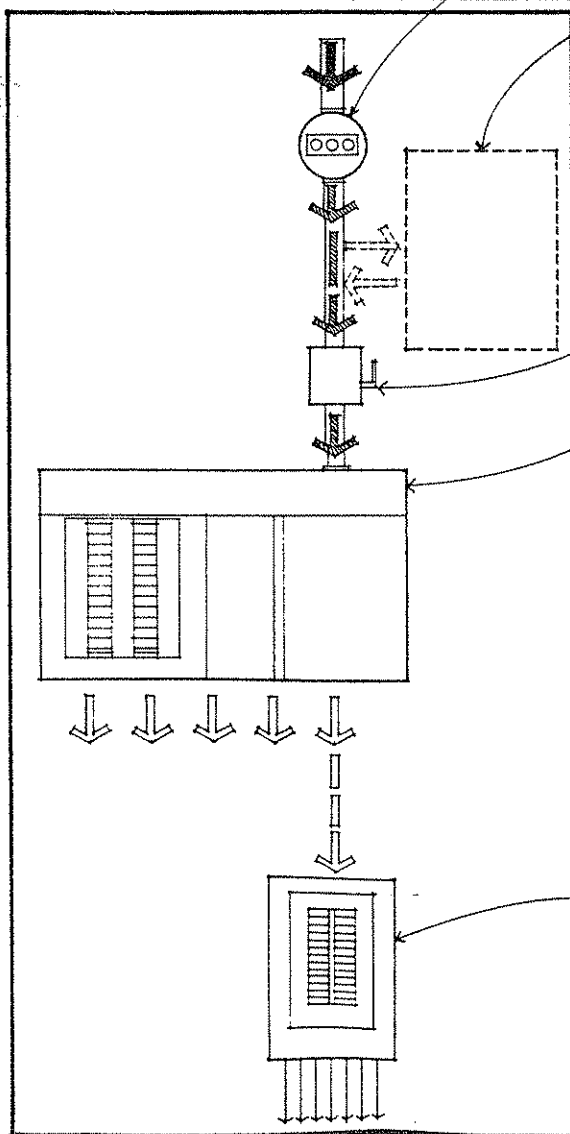
A transformer may be used by medium-sized and large buildings to switch from a high supply voltage to the service voltage. To reduce costs, maintenance, and noise and heat problems, transformers are usually placed outdoors. If located within a building, large transformers require a ventilated, fire-rated enclosure adjacent to the switchgear room. Dry-type transformers in small buildings may be placed in the main electric room.

The service switch is the main disconnect for the entire electrical system of a building, except for any emergency power systems.

The main switchboard controls and protects the main feeder lines of the electrical system.

- It consists of switches and circuit breakers which automatically open a circuit when an overload condition or short circuit occurs.
- It distributes the large incoming power supply into smaller, more easily controlled parcels.
- It should be as close as possible to the service connection to minimize voltage drop and for wiring economy.
- It may require an enclosure; check the applicable codes for requirements.
- Allow for both vertical and horizontal distribution of wiring and conduit in the construction around switchboards.

Panelboards control and protect the branch circuits of an electrical system. In large buildings, they are located in electrical closets close to the load ends of circuits. In residences and small installations, the distribution panels are combined with the switchboard to form a service panel.



ELECTRICAL CIRCUITS

Once the electrical power requirements for the various areas of a building are determined, wiring circuits must be laid out to distribute the power to the points of utilization. Panelboards, fed by the main switchboard, distribute the power supply into branch circuits. These panels may serve similar types of circuits (e.g., lighting circuits) or specific areas of a building.

- Branch circuits contain the final distribution points of the electrical system. Each branch circuit is sized according to the amount of load it must carry. About 20% of its capacity is reserved for flexibility, expansion, and safety. To avoid an excessive drop in voltage, a branch circuit should not exceed 100 feet in length. There are three types of branch circuits:

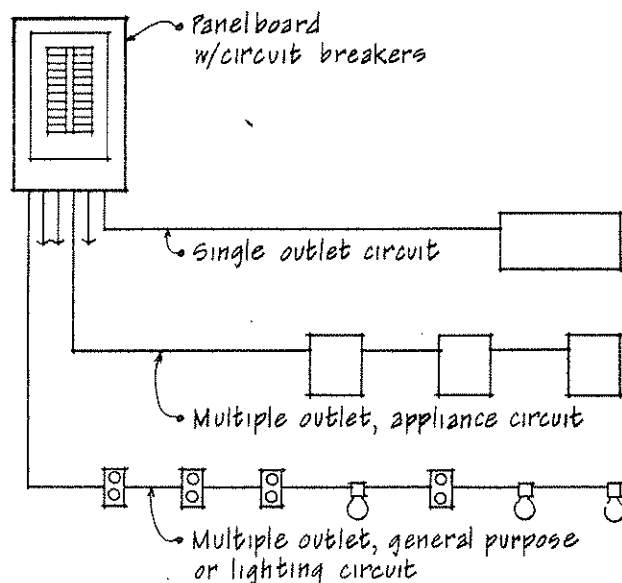
- Single outlet circuits are designed to serve a specific appliance or piece of equipment.
- Multiple outlet, appliance circuits are designed to serve a number of small appliances.
- Multiple outlet, general purpose circuits supply power for lighting and receptacles.

- Low voltage switching is used when a central control point is desired from which all switching may take place. The low voltage switches control relays which do the actual switching at the service outlets. Low voltage systems allow branch circuits to be shortened and their wiring can be run without conduit.

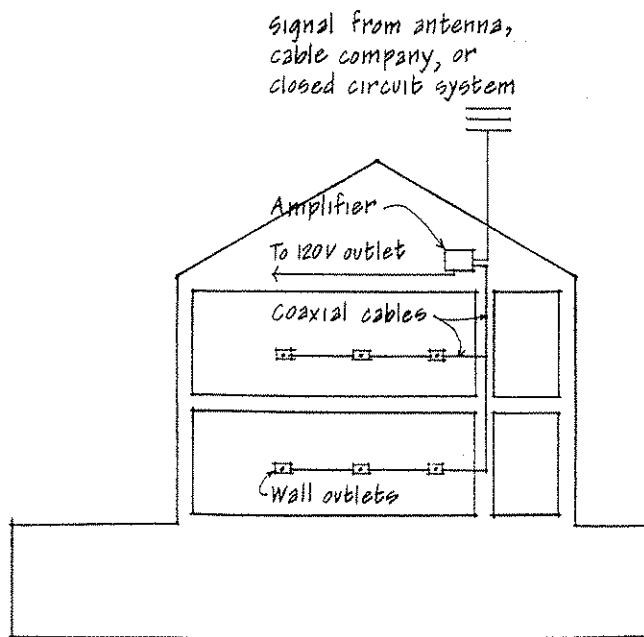
- Separate wiring circuits are required for the sound and signal equipment of telephone, cable TV, intercom, and security or fire alarm systems.

- Telephone systems should have their outlets located and wired during construction. Large installations also require a service connection, terminal enclosures, riser spaces, etc., similar to electrical systems. Large systems are usually designed, furnished, and installed by the telecommunications company.

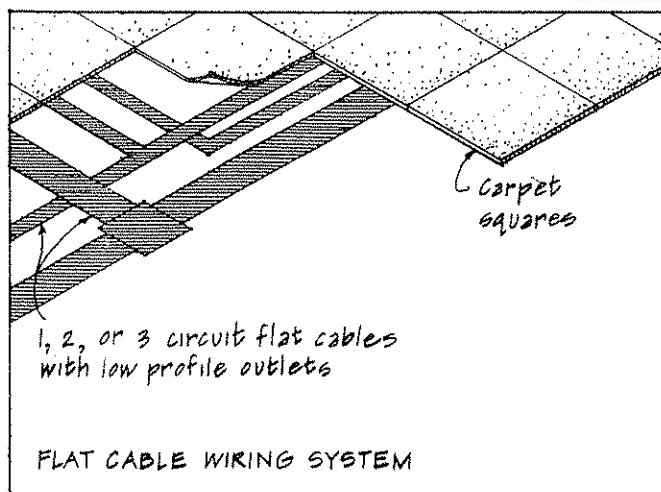
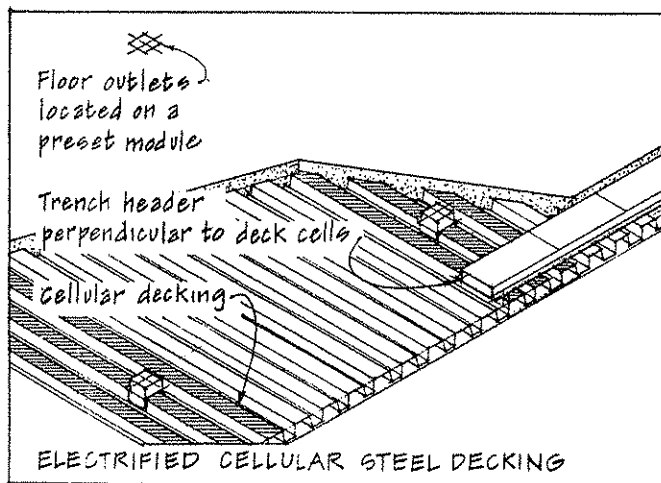
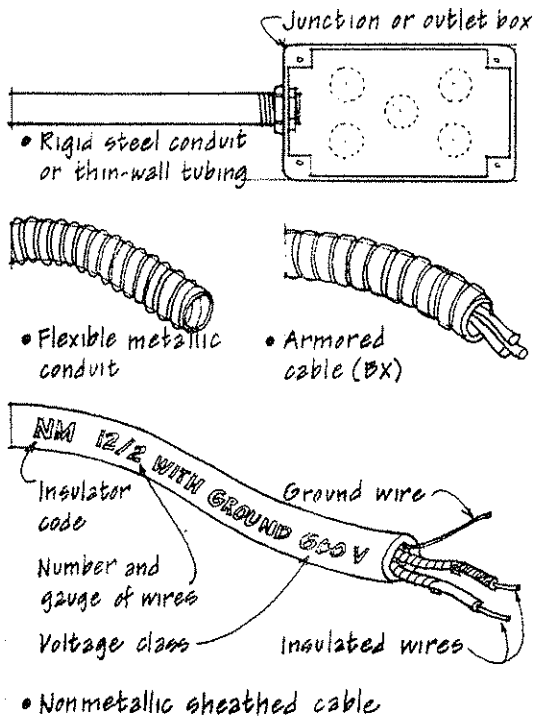
- Cable television systems may receive their signals from an outdoor antenna or satellite dish, a cable company, or a closed circuit system. If several outlets are required, a 120V outlet is supplied to serve an amplifier. Coaxial cables in a nonmetallic conduit or raceway transmit the amplified signal to the various outlets.



Receptacles in wet locations, such as in bathrooms, should be protected by a ground fault interrupter (GFI). A GFI device trips or breaks the circuit almost instantaneously when any leakage of current occurs. This protection may be provided by a GFI receptacle or by a GFI breaker at the service panel.



11.22 ELECTRICAL WIRING



Metals, offering little resistance to the flow of electric current, make good conductors. Copper is most often used. The various forms of conductors — wire, cable, and bus bars — are sized according to their safe current carrying capacity and their maximum operating temperature of their insulation. They are identified according to:

- Number and size of conductors
- Voltage class
- Type of insulation.

A conductor is covered with insulation to prevent its contact with other conductors or metal, and to protect it against heat, moisture, and corrosion. Materials with a high resistance to the flow of electric current, such as rubber, porcelain, glass, and some synthetics, are commonly used to insulate electrical wiring and connections.

Conduit provides support for wires and cables, protects them against physical damage and corrosion, and protects the surrounding area against fire hazards. Metal conduit also provides a continuous grounded enclosure for the wiring. For fireproof construction, rigid steel conduit, thin-wall metallic tubing, or flexible metallic conduit can be used. For frame construction, armored or nonmetallic sheathed cable is used. Plastic tubing and conduit is most commonly used for underground wiring.

Being relatively small, conduit can be easily accommodated in most construction systems. Conduit should be adequately supported and laid out as directly as possible. Codes generally restrict the radius and number of bends a run of conduit may have between junction or outlet boxes. Coordination with the building's mechanical and plumbing systems is required to avoid conflicting paths.

Electrical conductors may also be run within cellular steel decking or cellular raceways cast into the topping of concrete slabs. Flat wiring systems are also available for installation directly under carpeting.

For exposed installations, special conduit, raceways, troughs, and fittings are available. As with exposed mechanical systems, the layout should be visually coordinated with the physical elements of the space.

ELECTRICAL OUTLETS

11.25

Light fixtures, wall switches, and receptacle outlets are the most visible parts of an electrical system. Switches and receptacle outlets should be located for convenient access, and coordinated with visible surface patterns. Wall plates for these devices may be of metal, plastic, or glass, and are available in a variety of colors and finishes.

A receptacle outlet designed to serve a specific type of appliance will have a specific configuration so that only attachments from that of appliance will fit the receptacle. Outdoor receptacles should have a waterproof cover, and in all wet locations, receptacles should be protected by a ground fault interrupter.

Load requirements for light fixtures and electrically powered appliances and equipment are specified by their manufacturer. The design load for a general purpose circuit, however, depends on the number of receptacles served by the circuit and how they are used. Consult the applicable local code for the required number and spacing of receptacle outlets. The following can be used as a guide.

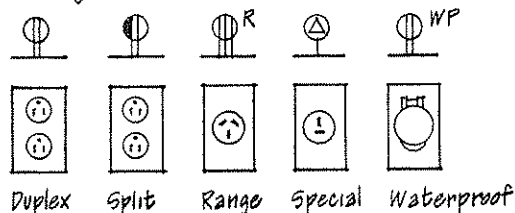
Residences:

- 1 outlet every 12' along walls in living areas
- 1 outlet every 4' along countertops in kitchens
- 1 GFI-protected outlet in bathrooms.

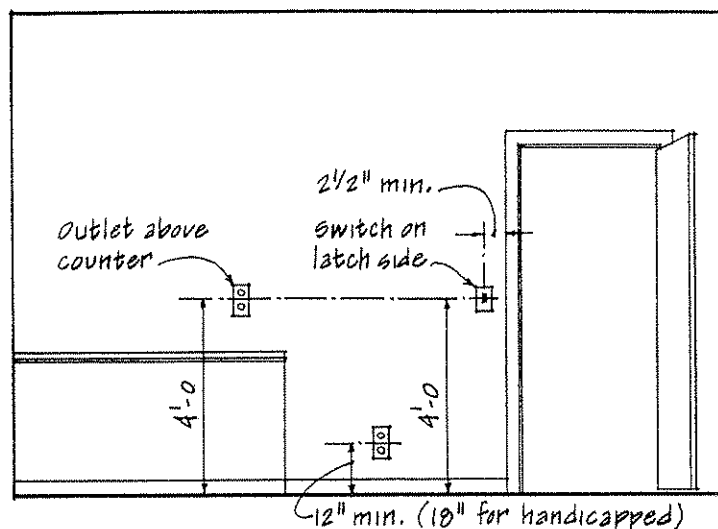
Offices:

- 1 outlet every 10' along walls, or
- 1 outlet for every 40 SF of floor area for the first 10 and
- 1 outlet for every 100 SF thereafter.

Plan symbols



EXAMPLES OF RECEPTACLE OUTLETS



HEIGHTS OF SWITCHES AND RECEPTACLE OUTLETS

	Panelboard, recessed		Fluorescent fixture
	Panelboard, surface		Ceiling incandescent
	Lighting panel		Wall incandescent
	Power panel		Track light
	Transformer		Recessed light
	Generator		Exit light outlet
	Motor		Special purpose outlet
	Disconnect switch		Television outlet
	Single pole switch		Chime
	3-way switch		Pushbutton
	Switch/receptacle		Fan receptacle
	Dimmer switch		Junction box
	Duplex outlet		Underfloor J-box
	Floor duplex outlet		Thermostat
	Telephone outlet		Computer data

EXAMPLES OF ELECTRICAL PLAN SYMBOLS

11.24 LIGHTING

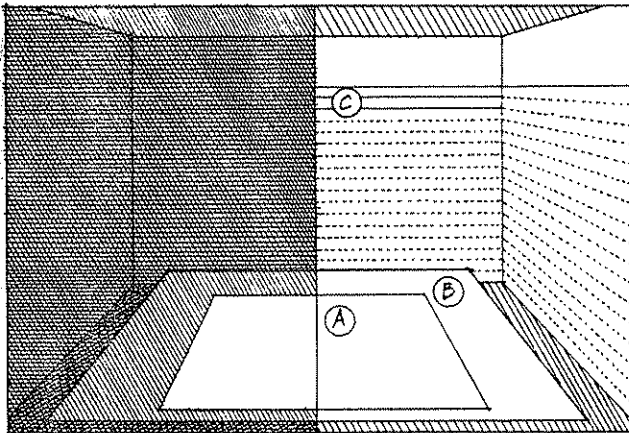
Task Difficulty	Footcandle (Fc) Level
Casual (dining)	20
Ordinary (reading)	50
Moderate (drafting)	100
Difficult (sewing)	200
Severe (surgery)	>400

1 Footcandle
= 1 lumen/ft²
= 10.76 lux

RECOMMENDED ILLUMINATION LEVELS

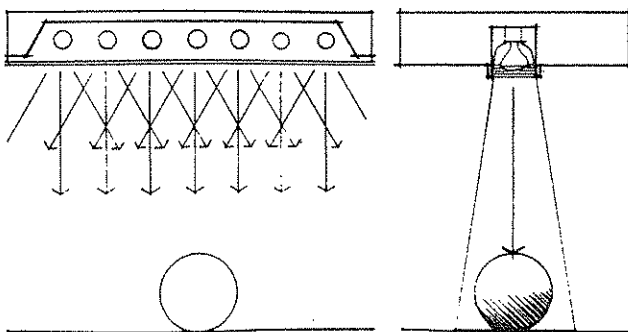
CONTRAST

The surrounding area (C) should range from 1/5 to 5 times the brightness of the visual task area (A).



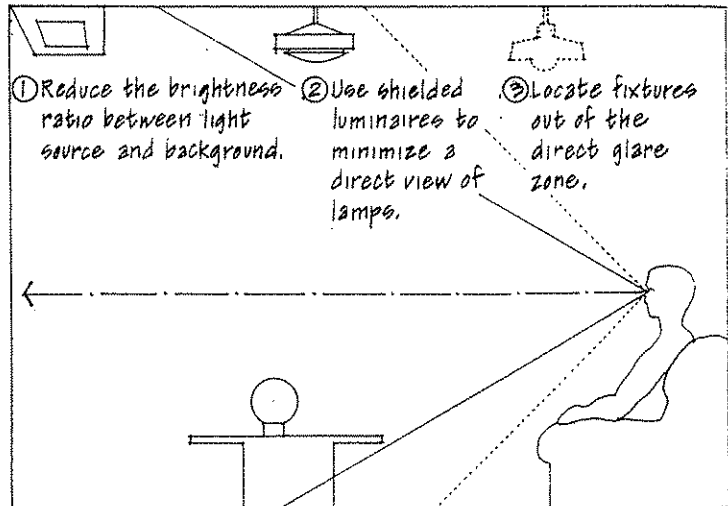
5:1 is the maximum recommended brightness ratio between the visual task area (A) and its immediate background (B).

BRIGHTNESS RATIOS



The primary purpose of a lighting system is to provide sufficient illumination for the performance of visual tasks. As a reference, recommended illumination levels for various categories of tasks are listed to the left. These illumination levels specify only the quantity of light to be supplied. How this light is supplied affects how a space is perceived or how an object is seen, and is just as important as the lighting level. The quality of a lighting system varies according to the brightness ratios in the space, the light's diffusion, and its color.

Contrast between the object viewed and its background is required for its form, shape, and texture to be seen. As the brightness level increases, the need for contrast decreases. When the contrast in brightness becomes excessive, glare can result and cause discomfort for the viewer. Excessive brightness ratios can occur between a light source and its background or between adjacent surfaces in a space.



POSSIBLE SOLUTIONS TO DIRECT GLARE

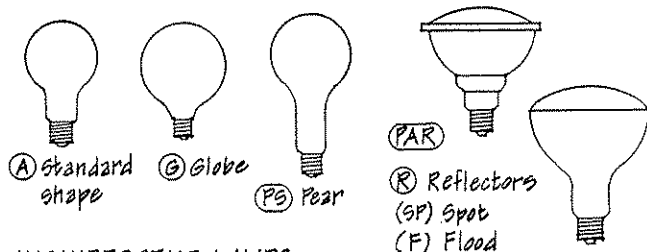
Diffused light emanates from broad or multiple light sources and reflecting surfaces. It produces fairly uniform illumination with few shadows. Directional light, on the other hand, produces brightness variations and shadows which are necessary for the perception of shape, form, and texture. A mix of diffused and directional lighting is often desirable and beneficial, especially when a variety of tasks are to be performed in a room.

The perceived color of a surface is the result of its ability to reflect or absorb the color of the light falling on it. The spectral distribution of a light source is important because if certain wavelengths of color are missing, then those colors cannot be reflected and will appear to be missing in any surface illuminated by that light.

LIGHT SOURCES

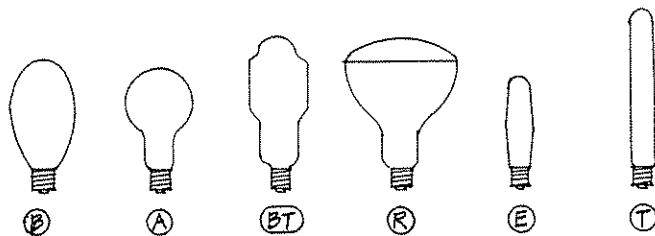
Artificial light is natural light that is produced by manufactured elements. The quantity and quality of light produced differ according to the type of lamp used. The light is further modified by the housing that holds and energizes the lamp.

There are three major types of artificial light sources, incandescent, fluorescent, and high intensity discharge (HID) lamps. For accurate, current data on lamp sizes, wattages, lumen output, and average life, consult the lamp manufacturers' catalogs.

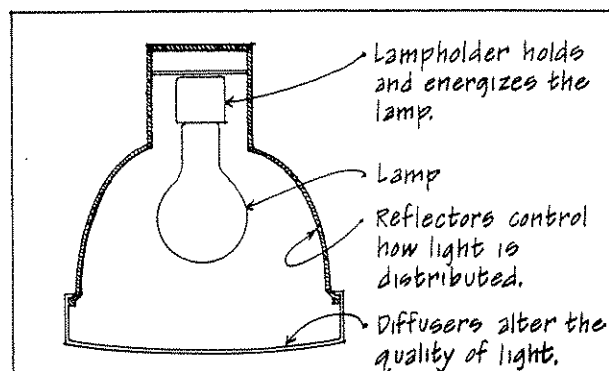


INCANDESCENT LAMPS

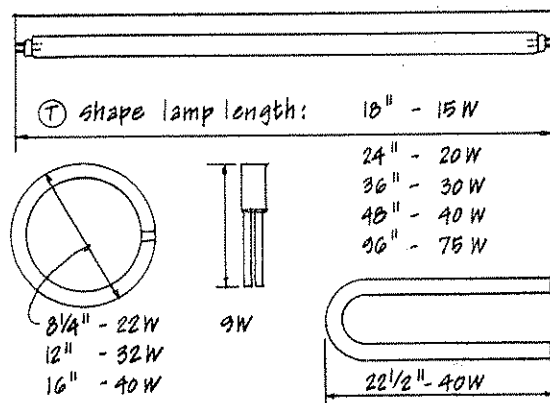
- Lamp designation: A-10 ← Bulb diameter in eighths of an inch
 - Point light source
 - Low efficacy (12%)
 - Good color rendition
 - Easy to dim w/ rheostats
- Bulb shape



HID LAMPS Mercury vapor, high pressure sodium, and metal halide lamps combine the form of an incandescent lamp with the efficiency of a fluorescent.



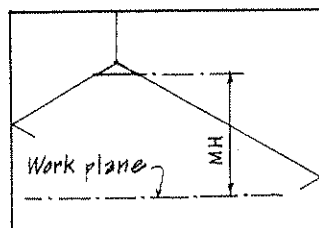
The term luminaire refers to the entire lighting unit, consisting of the lamp or lamps, the connection to the power supply, the mounting mechanism, and elements that shield, reflect, or diffuse the light.



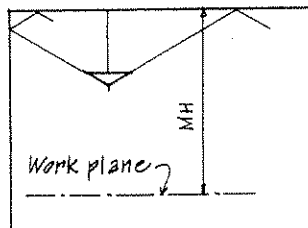
FLUORESCENT LAMPS

- Linear light source
- Color rendition varies
- 50 to 80 lumens/watt

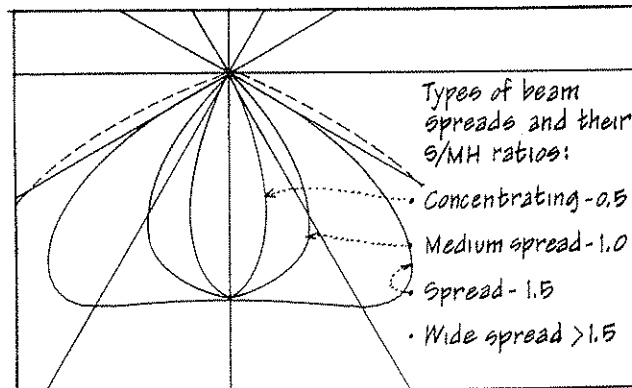
The S/MH guideline specifies the ratio of maximum luminaire spacing to mounting height that is necessary to achieve an acceptable uniformity of illumination. S/MH ratios are calculated and supplied by the luminaire manufacturer.



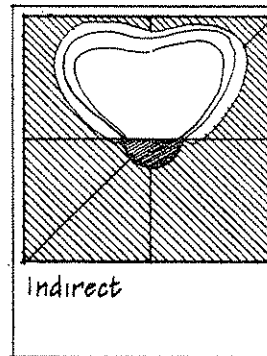
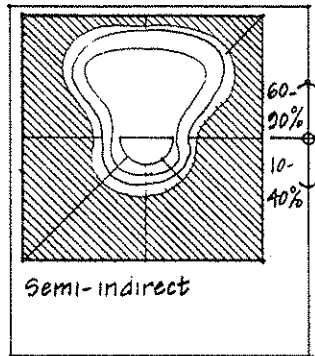
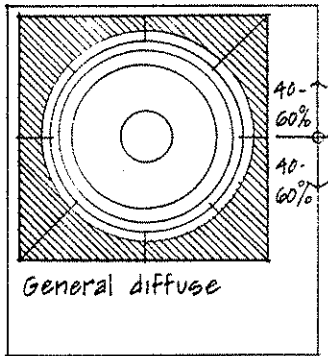
Direct lighting of the visual task surface



Indirect lighting, using the ceiling as a reflector

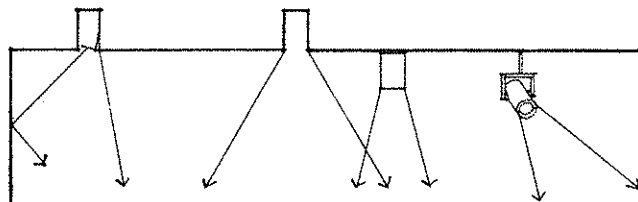


11.26 LIGHTING APPLICATIONS



These types are based on the percentage of light emitted above and below the horizontal The actual distribution of a specific luminaire is determined by the type of lamp used and the fixture design. Consult the manufacturer's catalog.

TYPES OF LUMINAIRE DISTRIBUTION



Downlights:

- Recessed or surface-mounted
- Light distribution pattern depends on type of lamp, lens, and reflector housing used.
- Used to provide local lighting or to illuminate wall surfaces.

Adjustable fixtures:

- Similar to downlights
- Fixture direction is adjustable
- Track mounting allows light source to be relocated.

Suspended fixtures:

- Dome fixtures provide direct-spread illumination.
- Uniformity of illumination depends on spacing and overlap of light distribution patterns.
- Closely spaced fixtures can define a secondary ceiling plane.



Coffer light panels:

- Illumination is diffused through a prismatic lens or reflected off surfaces.



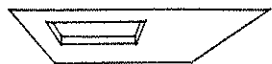
Flush light panels:

- Isolated squares, continuous light strips, or a luminous ceiling

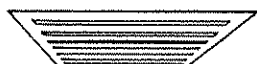


Surface-mounted or suspended luminaires:

- Surface-mounted fixtures are similar to flush light panels.
- Suspended fixtures may provide direct or semidirect illumination.



- Coffers produce a skylight effect and minimize glare.



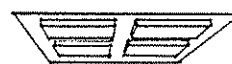
- Increases apparent width and potential for glare



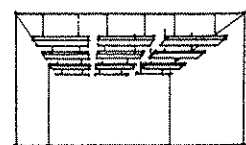
- Increases apparent length Provides direction Decreases glare



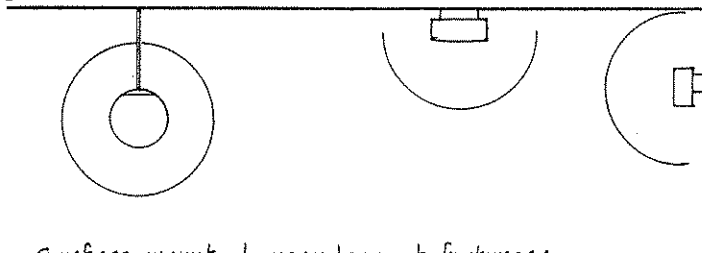
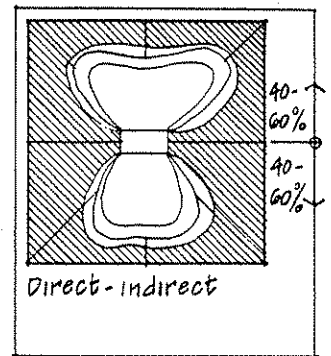
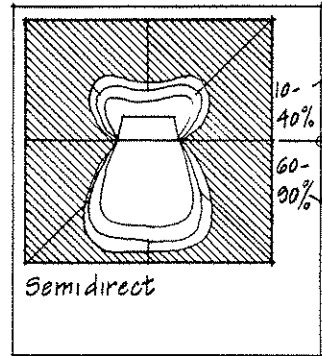
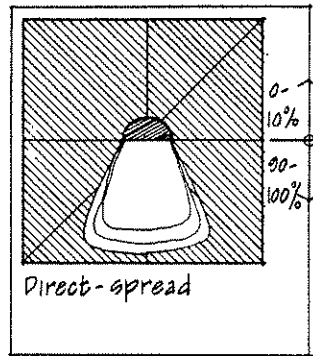
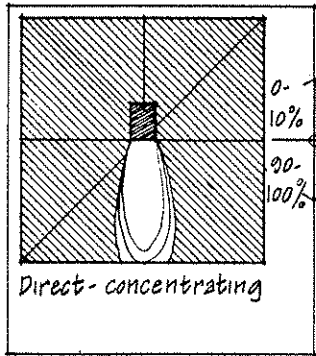
- Interrupts rectangular pattern and minimizes shadows



- Square fixtures are more visually dominant and less directional than linear fixtures.
- Fixtures give ceiling surface depth.



- Suspended fixtures can lower the apparent ceiling height of a space.



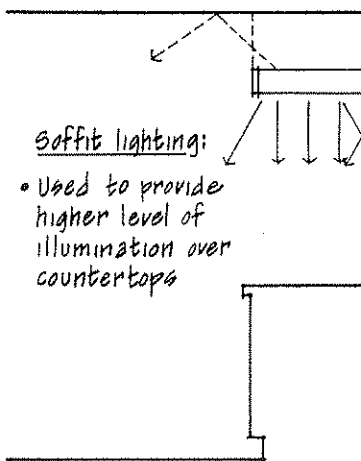
Surface-mounted incandescent fixtures:

Translucent enclosures minimize the brightness ratio between the light source and the surrounding surface.

Low wattage lamps may be left exposed.

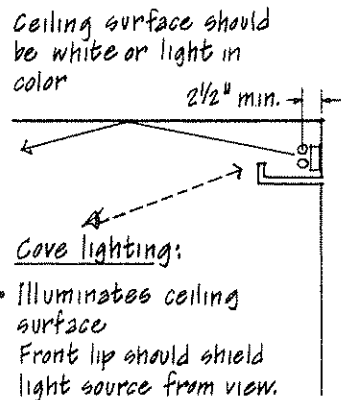
Fixtures similar to downlights may be wall-mounted to provide direct-indirect illumination.

Low wall-mounted fixtures are used to illuminate corridors and walkways.



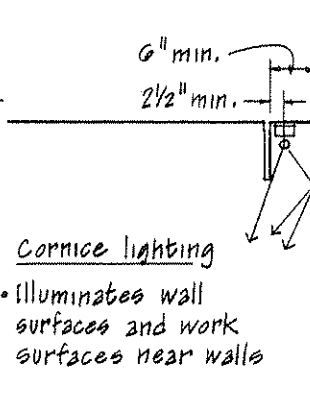
Soffit lighting:

- Used to provide higher level of illumination over countertops



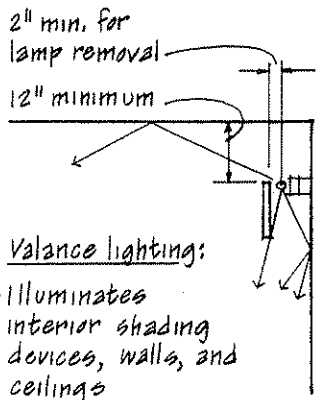
Cove lighting:

- Illuminates ceiling surface
Front lip should shield light source from view.



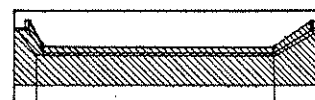
Cornice lighting

- Illuminates wall surfaces and work surfaces near walls

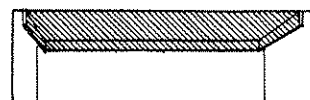


Valance lighting:

- Illuminates interior shading devices, walls, and ceilings



- Illuminated ceiling surface

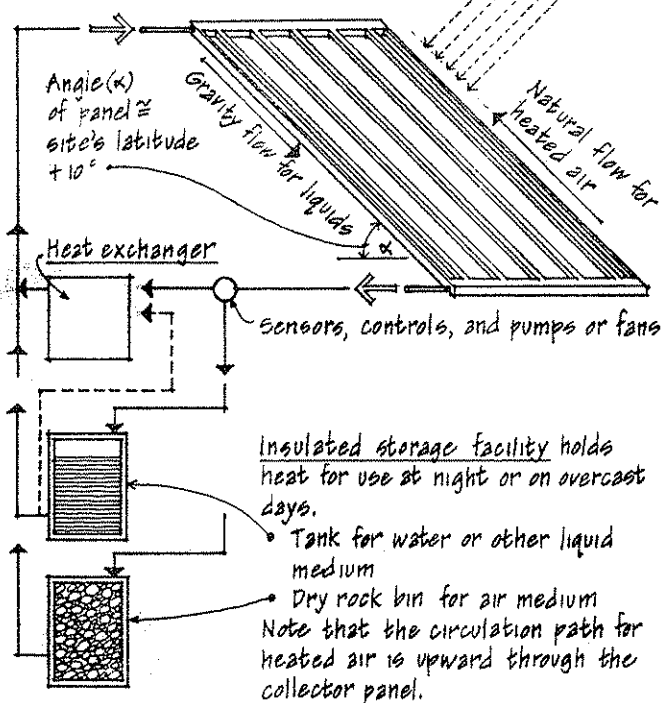
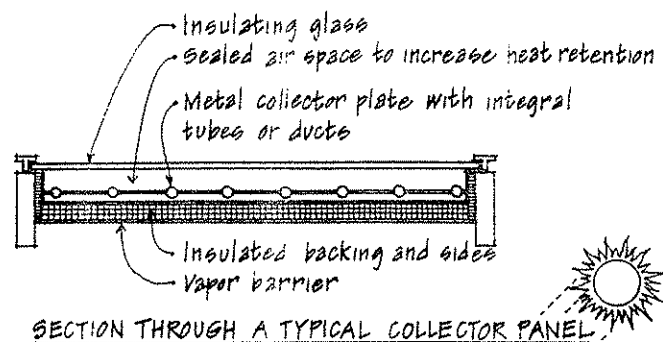


- Illuminated wall surfaces



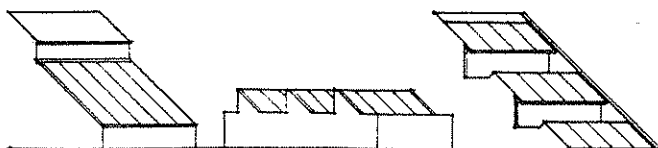
- Illuminated wall and ceiling surfaces.

11.28 ACTIVE SOLAR ENERGY SYSTEMS



The heating and cooling components of the solar energy system are similar to those of conventional systems.

- For heating: Air-water or all-air system
- For cooling: A heat pump or absorption cooling unit is required.
- A backup heating system is recommended.



- Collector panels may form a single plane or a series of parallel planes.
- Locating the panels away from the building requires a longer and less efficient distribution run for the heat transfer medium.

Active solar energy systems absorb, transfer, and store energy from solar radiation for building heating and cooling. They normally consist of the following components:

- Solar collector panels
- Circulation and distribution system for the heat transfer medium
- Heat exchanger and storage facility

The solar collector panels are the system's prime components. They should be oriented within 20° of true south and not be shaded by nearby structures, terrain, or trees. The required collector surface area depends on the heat exchange efficiency of the collector and heat transfer medium, and the building's heating and cooling load. Current recommendations range from $1/3$ to $1/2$ of the building's net floor area.

The heat transfer medium (air, water, or other liquid) carries the collected heat energy from the solar panels to the heat utilization equipment or to a storage utility for later use.

Liquid medium:

- Piping is used for circulation and distribution.
- An antifreeze solution provides freeze protection.
- A corrosion-retarding additive is required for aluminum pipes.

Air medium:

- Ductwork for air collectors requires more installation space.
- Larger collector surfaces are also required since heat transfer coefficient for air is less than that of liquids.
- Panel construction is simpler and not subject to problems of freezing, leakage, and corrosion.

For an active solar energy system to be efficient, the building itself must be thermally efficient and well insulated. Its siting, orientation, and window openings should take advantage of the sun's summer and winter solar radiation. See 1.12 for passive solar design.

Solar collector panels are normally integral parts of a building's roof or wall systems. Their large surface area therefore has a strong influence on a building's exterior form and image.

NOTES ON MATERIALS

12

This chapter describes the major types of building materials, their physical properties, and their uses in building construction.

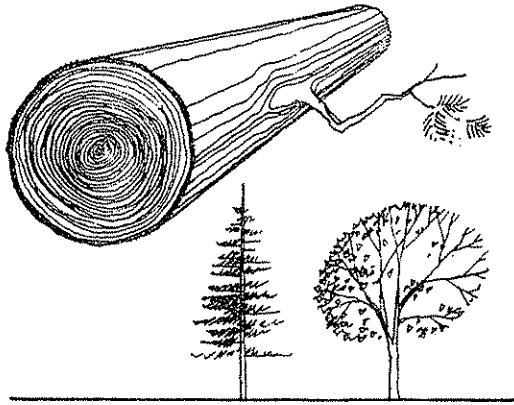
Each building material has distinct properties of strength, elasticity and stiffness, density or hardness, resistance to wear, fire-resistance, and thermal conductivity. The most effective structural materials are those which combine elasticity with stiffness. Elasticity is the ability of a material to deform under stress—bend, stretch, or compress—and return to its original shape when the applied stress is removed. Every material has its elastic limit beyond which it will permanently deform or break. Materials which undergo plastic deformation before actually breaking are termed ductile. Brittle materials, on the other hand, have low elastic limits and rupture under loads with little visible deformation. Because brittle materials have less reserve strength than ductile materials, they are not as suitable for structural purposes.

Stiffness is a measure of the force required to push or pull a material to its elastic limit. A material's stiffness, along with the stiffness of its cross-sectional shape, are important factors when considering the relationship between span and deflection under loading.

Many building materials are manufactured in standard shapes and sizes. These stock dimensions, however, may vary slightly between manufacturers. They should be verified in the planning and design phases of a building so that unnecessary cutting or wasting of material can be minimized during construction.

Following the discussion of building materials is an outline of the various materials and methods used to fasten and finish materials.

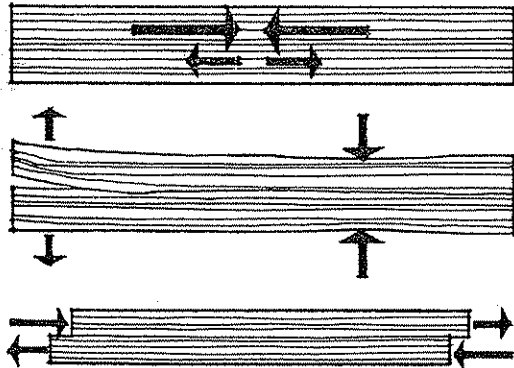
12.2 WOOD



As a construction material, wood is strong, durable, light in weight, and easy to work. In addition, it offers natural beauty and warmth to sight and touch. Although it has become necessary to employ conservation measures to ensure a continued supply, wood is still used in construction in many and varied forms.

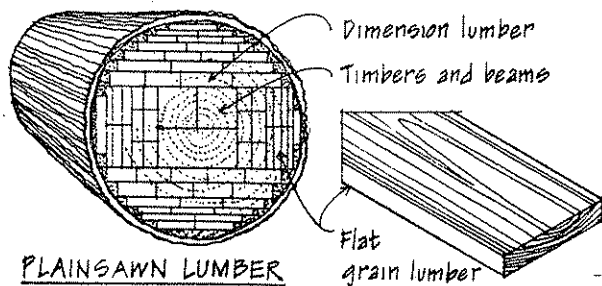
There are two major classes of wood: softwood and hardwood. These terms do not indicate the relative hardness, softness, or strength of a wood. Softwoods are the evergreens, and are used for general construction. Hardwoods come from deciduous or broadleaf trees, and are typically used for flooring, stairs, paneling, furniture, and interior trim.

The manner in which a tree grows affects its strength, its susceptibility to expansion and contraction, and its effectiveness as an insulator. Tree growth also affects how pieces of sawn wood (lumber) may be joined to form structure and enclosure.



Grain direction is the major determining factor in the use of wood as a structural material. Tensile and compressive forces are best handled by wood in a direction parallel to its grain. Typically, a given piece of wood will withstand $\frac{1}{3}$ more force in compression than in tension parallel to its grain. The allowable compressive force perpendicular to its grain is only about $\frac{1}{5}$ to $\frac{1}{2}$ of the allowable compressive force parallel to the grain. Tensile forces perpendicular to the grain will cause the wood to split.

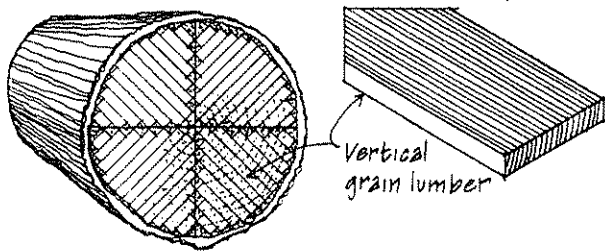
Wood's shear strength is greater across its grain than parallel to the grain. It is therefore more susceptible to horizontal shear than to vertical shear.



The manner in which lumber is cut from a log affects its strength as well as its appearance.

Plainsawn lumber:

- may have a variety of noticeable grain patterns
- tends to twist and cup, and wears unevenly
- tends to have raised grain
- shrinks and swells less in thickness, more in width.



Quartersawn lumber:

- has more even grain patterns
- wears more evenly with less raised grain and warping
- shrinks and swells less in width, more in thickness
- is less affected by surface checks
- is more expensive and results in more waste in cutting.

To increase its strength, stability, and resistance to fungi, decay and insects, wood is seasoned by air-drying (a lengthy process) or through the use of kilns. It is impossible to completely seal a piece of wood to prevent changes in its moisture content. Below a moisture content of about 30%, wood expands as it absorbs moisture and shrinks as it loses moisture. This possibility of shrinkage and swelling must always be taken into account when detailing and constructing wood joints, both in small and large scale work.

Shrinkage tangential to the wood grain is usually twice as much as radial shrinkage. Vertical grain lumber shrinks uniformly while plainsawn cuts near a log's perimeter will cup away from the center.

The thermal expansion of wood is generally much less than volume changes due to changes in moisture content. Moisture content is therefore the controlling factor.

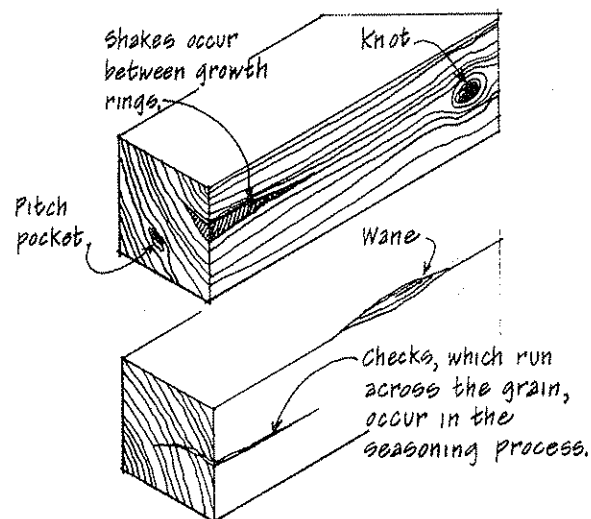
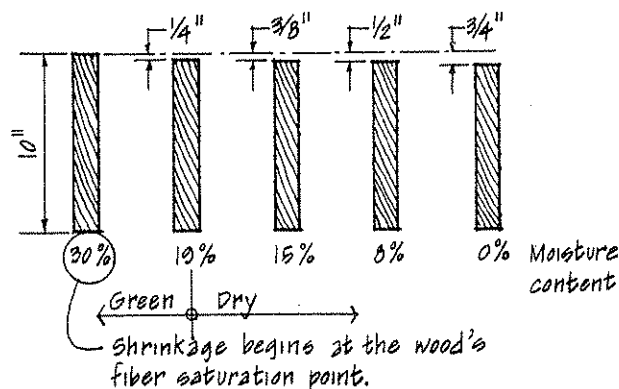
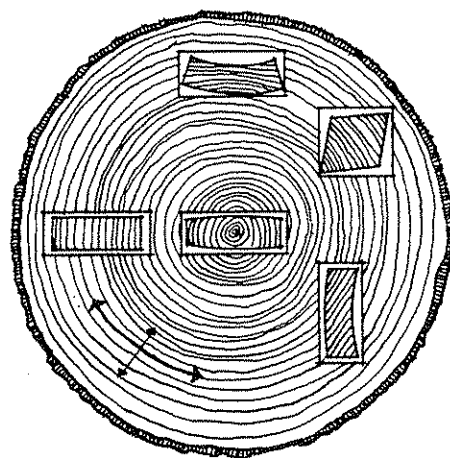
Wood defects affect the grading, appearance, and use of the wood. They may also affect the wood's strength, depending on their number, size, and location. Defects include the natural characteristics of wood, such as knots, shakes, and pitch pockets, as well as manufacturing characteristics, such as splits, checking, and warp.

Wood is decay-resistant when its moisture content is under 20%. If installed and maintained below this moisture content level, wood will not rot.

Species that are naturally resistant to decay-causing fungi include redwood, cedar, bald cypress, black locust, and black walnut. Insect-resistant species include redwood, eastern red cedar, and bald cypress.

Preservative treatments are available to further protect wood from decay and insect attack. Of these, pressure treatment is the most effective, especially when the wood is in contact with the ground. There are three types of preservatives.

- Water-borne preservatives leave the wood clean, odorless, and readily paintable; preservatives do not leach out when exposed to weather. → AWPB (American Wood Preservers Bureau) LP-2 (LP-22 for ground contact)
- Oil-borne preservatives may color the wood, but treated wood is paintable; pentachlorophenol is highly toxic. → AWPB LP-3 (LP-33 for ground contact)
- Creosote treatment leaves wood with colored, oily surfaces; odor remains for a long period; used especially in marine and salt water installations. → AWPB LP-5 (LP-55 for ground contact)



12.4 LUMBER

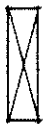
Nominal thickness or width	Minimum dressed size of dry lumber; moisture content <10%	Note: Lumber is measured in board-feet; 1 board-foot = 1" x 12" x 1 foot of length (nominal)
1"	3/4"	Lumber is specified according to its nominal dimensions. The nominal size is the lumber's rough, unfinished size. The dressed, actual size is smaller due to the seasoning and surfacing of the lumber before use. The face dimension is the finished width of a piece that is exposed to view after installation. Lumber is commonly available in lengths from 6' to 24', in multiples of 2'.
2"	1 1/2"	
3"	2 1/2"	
4"	3 1/2"	
5"	4 1/2"	
6"	5 1/2"	
8"	7 1/4"	
10"	9 1/4"	
12"	11 1/4"	
14"	13 1/4"	

Because of the diversity of its applications and its use for remanufacturing purposes, hardwood is graded according to the amount of clear, usable lumber in a piece that may be cut into smaller pieces of a certain grade and size. Softwood is classified in the following manner.

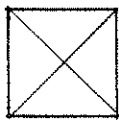
YARD LUMBER



- Boards
- 1" to 1 1/2" thick; 2" and wider
- Graded for appearance rather than strength
- Used as siding, subflooring, interior trim



- Dimension lumber
- 2" to 4" thick; 2" and wider
- Graded for strength (stress-graded) rather than appearance
- Used for general construction
- Light framing 2" to 4" wide
- Joists and planks 6" and wider
- Decking 4" and wider (Select and Commercial grades)



- Timbers
- 5" x 5" and larger
- Graded for strength and serviceability
- Often stocked in green, undressed condition
- May be classified as structural lumber along with joists and planks

FACTORY AND SHOP LUMBER Used primarily for remanufacturing purposes (doors, windows, millwork)

Lumber may be structurally graded as follows (in descending order, according to stress grade).

- Light framing: construction, standard, utility grades
- Structural light framing, joists and planks: Select structural, No 1, 2, and 3 grades; some species may also have an appearance grade for exposed work.
- Timber: Select structural and No 1 grades

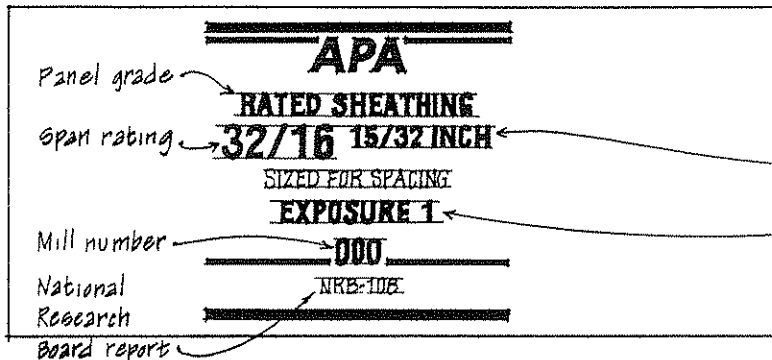
Lumber may be appearance graded as follows.

- Select: A, B, or B and better, used for natural finishes.
C, D, for painted finishes
- Common: for general construction

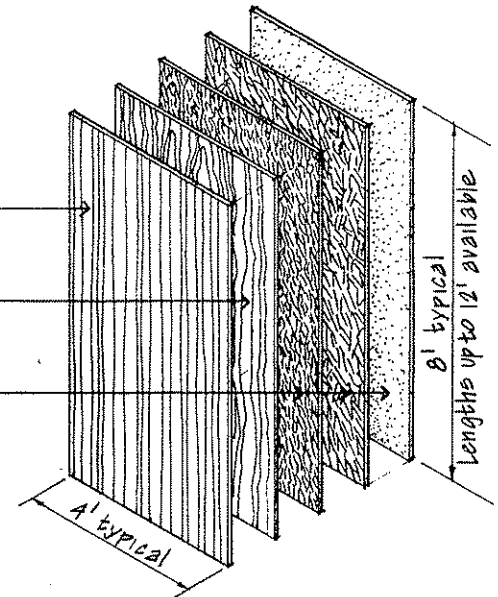
Wood panel products are less susceptible to shrinking or swelling, require less labor to install, and make more efficient use of wood resources than solid wood products. The major types of wood panel products are:

- Plywood is a laminated panel of wood veneers laid with their grain direction at right angles to one another.
- Composite panels consist of 2 face veneers bonded to wood fiber cores.
- Nonveneer panels consist of wood strands, flakes, or particles which are compressed and bonded together under pressure (e.g., oriented strand board, waferboard, particleboard).

Engineered panel grades have relatively high shear strength for loads perpendicular to the panel face. They are therefore used for wall and roof sheathing, subflooring, and underlayment. Most structural panels have a grade-stamp on their back with the following information.



TYPICAL APA (American Plywood Association)
PERFORMANCE-RATED PANEL REGISTERED
TRADEMARK.



Veneer grades:

- N Smooth, "natural finish" veneer
- A Smooth, paint-grade
- B Smooth, with plugs and tight knots
- C Sheathing grade
- D Limited to interior panels

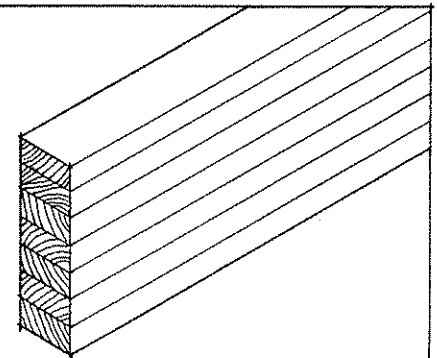
Thicknesses: 1/4" to 1 1/8"

Exposure classifications:

- Exterior - 100% waterproof glue line for permanent exposure to weather
- Exposure 1 - Bonded with exterior glue to resist moisture during construction
- Exposure 2 - Bonded with intermediate glue for moderate exposure to moisture

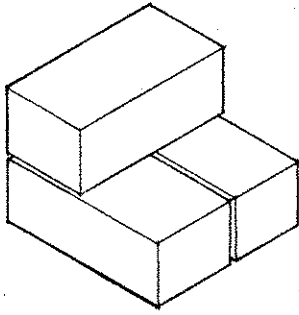
Laminated timbers are engineered, stress-rated structural members. They are built up of several layers of wood which are securely bonded with waterproof or water-resistant glue. The grain of the laminations are approximately parallel and run longitudinally. Several grades of lumber may be used - the higher grades in areas of highest stress, the lower grades in areas of lower stress.

For large structural members, laminated timber is preferable to solid timber in terms of appearance, weather resistance, controlled moisture content, and available sizes. Being factory-made, laminated timbers are consistent in size, appearance and strength, and more dimensionally stable than solid timber.



* See 4.15 for typical sizes and spans.

12.6 MASONRY



Masonry refers to building blocks which are formed and hardened into modular units. This modular aspect (i.e., uniform size and proportional relationships) distinguishes masonry from most of the other construction materials discussed in this chapter.

Masonry units are formed from shapeless material and hardened in one of two ways.

① Through heat:

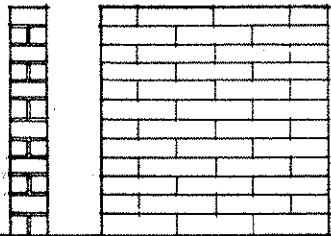
Brick
Structural clay tile
Terra cotta

Made from various types of clay

② Through chemical action:

Concrete block
Concrete brick
Gypsum block

Made from a mixture of cement or gypsum, aggregate, and water



Compared to wood, steel and concrete, masonry units and the mortar used to bond them together are relatively weak. Masonry units should therefore be laid up in such a way that the entire masonry mass acts as an entity. See 5.10 to 5.21 for structural requirements and types of masonry walls.

Masonry is structurally most effective in compression. The following are minimum compressive strength values for various types of masonry units.

It should be noted that the allowable compressive stresses in unreinforced masonry walls are much less than the values given here since the quality of the masonry units, mortar, and workmanship may vary. See table on 5.10 for these values.

BRICK	2500 psi	Type SW	(severe weather) for use below grade and where exposed to freezing	
	2200 psi	Type MW	(Medium weather) for walls above grade	
	1250 psi	Type NW	(No weather) for interior use	
CONCRETE MASONRY UNITS	800 psi	Type N	Hollow loadbearing units	Type S units are limited to walls not exposed to the weather.
	600 psi	S		
	1500 psi	Type N	Solid loadbearing units	
	1000 psi	S		
	3000 psi	Type N	Concrete brick units	
	2000 psi	S		

Mortar consists of:

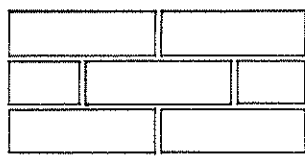
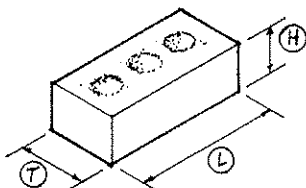
- Portland and/or masonry cements
- Clean, well-graded sand
- Water
- Lime used in portland cement-lime mortars to enhance workability, water retention, and flexibility.

The mortar used to bond the masonry units together can also be graded according to compressive strength and use.

MORTAR	2500 psi	Type M	For basements, foundations, and reinforced masonry
	1800 psi	Type S	For exterior walls and interior loadbearing walls
	750 psi	Type N	For interior walls and solid masonry veneers

(See also table on 5.10.)

BRICK SIZES



See 5.20 for bonding patterns

Brick unit type

Nominal dimensions (inches)

T

H

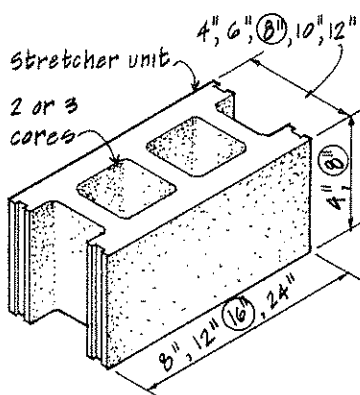
L

Modular coursing (inches)

Standard modular	4	2 2/3	8	3C = 8
Engineer	4	3 1/6	8	5C = 16
Economy	4	4	8	1C = 4
Double	4	5 1/3	8	3C = 16
Roman	4	2	12	2C = 4
Norman	4	2 2/3	12	3C = 8
Norwegian	4	3 1/6	12	5C = 16
Utility	4	4	12	1C = 4
Triple	4	5 1/3	12	3C = 16
SCR brick	6	2 2/3	12	3C = 8
6" Norwegian	6	3 1/6	12	5C = 16
6" Jumbo	6	4	12	1C = 4
8" Jumbo	8	4	12	1C = 4
8" Square	4	8	8	1C = 8

The actual dimensions of brick units vary due to shrinkage during the manufacturing process. The nominal dimensions given above include the thickness of the mortar joints, which may vary from 1/4" to 1/2".

CONCRETE MASONRY UNITS



Nominal dimensions, including thickness of mortar joints

The basic unit of concrete masonry is the concrete block. There are three types of concrete block.

- Solid loadbearing units (75% or more net area)
- Hollow loadbearing units
- Hollow nonloadbearing units

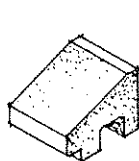
Aggregates, which constitute about 90% of the block by weight, affect the strength and other properties of the finished unit. There are two types of aggregate used.

- Normal weight
Sand and gravel; 40 lbs. per block unit
Compressive strength: 1200 to 1800 psi
Density: 130 to 145 lbs./cu.ft.
Low absorption
- Lightweight
Expanded shale, expanded slag, cinders, or pumice
22 to 28 lbs. per block unit
Compressive strength: 700 to 1500 psi
Density: 75 to 105 lbs./cu.ft.

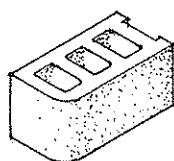


Concrete brick

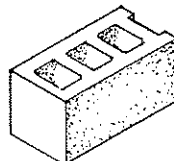
Concrete masonry units are manufactured in many shapes to satisfy various construction conditions. Their availability varies with locality and manufacturer.



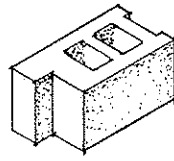
Gash



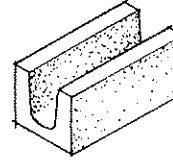
Bullnose



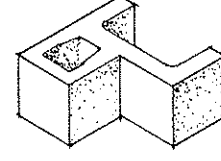
Corner



Jamb



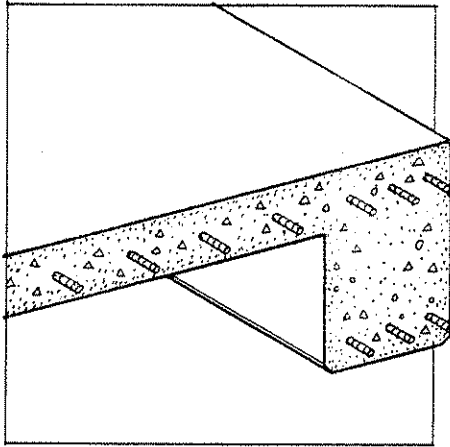
Lintel



Pilaster

Units may have scored, fluted, ribbed, or split faces.
See 5.31 for bonding patterns.

12.8 CONCRETE



Concrete is widely used in construction because it combines many of the advantages of wood, steel, and masonry. It is inherently strong in compression. To handle tensile and shear stresses, it can encase and bond with steel reinforcement. It is capable of being formed into almost any shape with a variety of surface finishes, textures, and patterns. (See 5.47) In addition, concrete structures are relatively low in cost and inherently fire resistant.

Concrete's liabilities include its weight (150 lbs./cu.ft. for normal reinforced concrete) and the forming or molding process that is required before it can be placed to set and cure.

Concrete consists of two parts, cement paste and aggregate, which are mixed from four ingredients.

CEMENT PASTE

- ① Portland cement
 - Type I... Normal - a general purpose cement
 - Type II... Moderate - for moderate resistance to sulfate attack
 - Type III... High early strength - used when a high strength is desired within a short curing period (3 to 7 days)
 - Type IV... Low-heat - used to minimize the heat of hydration in large concrete masses, such as dams
 - Type V... Sulfate-resisting - for construction exposed to severe sulfate attack

Types IA, IIA, and IIIA correspond to types I, II, and III, but contain air-entraining materials which make the concrete more workable and more resistant to severe frost action.

- ② Water... Should be clean, free of organic material, alkali, sulfates, oil; a general criterion is that the water should be drinkable

AGGREGATE

- ③ Fine aggregate... Well-graded sand up to 1/4"
- ④ Coarse aggregate... Gravel or crushed rock from 1/4" to 1 1/2"

Aggregate should be clean, durable, and free of organic matter.

- Lightweight aggregate... Expanded shale, slate and slag are used to reduce the weight of structural concrete while retaining most of its strength. Vermiculite and perlite are used to produce low density, insulating concrete.

ADMIXTURES

- Air-entraining agents... Added to improve workability and resistance of concrete to severe frost action and the effects of salts applied for snow and ice removal.
- Accelerators... Added to increase the rate of curing and early strength development.
- Retarders... Added to retard the set of the concrete in hot weather or when more time to work the wet concrete is desired; retarders also act as water-reducing agents.
- Plasticizers... Added to make the concrete easier to place in forms.
- Coloring dyes and pigments... Added for coloration.

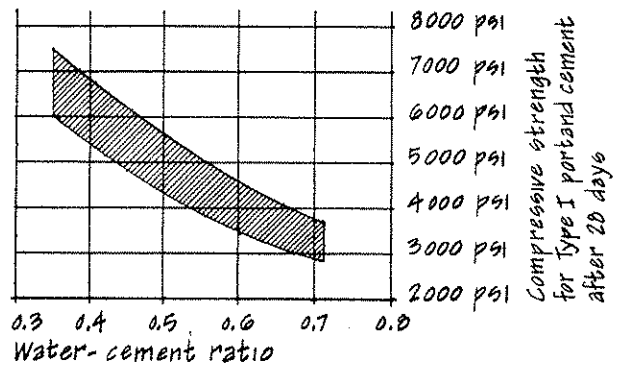
The quality of a concrete product depends on the characteristics of its ingredients, the proportions of the mix, and the manner in which it is placed, finished, and cured.

The potential strength of concrete is determined primarily by its water-cement ratio. Theoretically, the strength of concrete will increase as the amount of water used per unit weight of cement decreases. If too much water is used, the concrete mix will be weak and porous after curing. If too little water is used, however, the mix will be dense but difficult to place and work. For most applications, the water-cement ratio should range from 0.45 to 0.60 (weight of water = 45% to 60% of the weight of the cement). The actual water-cement ratio used should be appropriate for the desired strength, workability, durability, and watertightness of the concrete.

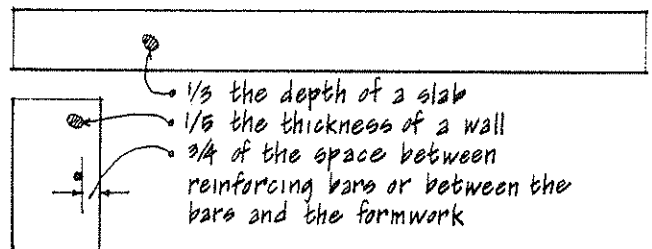
The most economical mix occurs when the fine and coarse aggregates are evenly graded so that a minimum amount of cement paste is required to surround all of the aggregate and fill the spaces in between. The proportion of fine to coarse aggregate, and the maximum size of coarse aggregate that may be used, depend on the method of placement, the steel reinforcement of the concrete section, and the finishing requirements.

Steel is used to resist the tensile stresses in reinforced concrete, and to resist the cracking that may occur because of curing shrinkage or thermal expansion and contraction. Concrete columns and beams sometimes require steel to handle some of their compressive stresses as well.

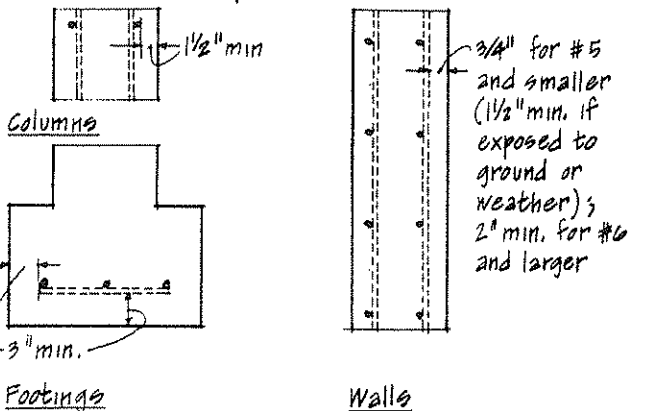
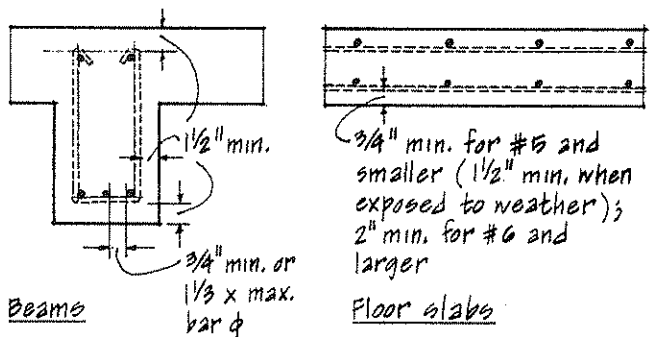
Reinforcing steel must be protected from fire and corrosion by a covering thickness of concrete.



Concrete is normally specified according to the compressive strength it will develop within 28 days after placement (7 days for high-early-strength concrete).



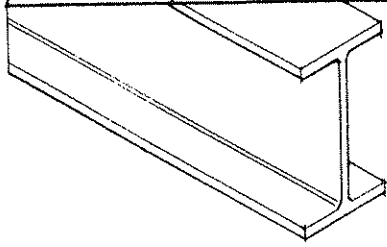
MAXIMUM AGGREGATE SIZE



MIN. CONCRETE COVER FOR REINFORCEMENT

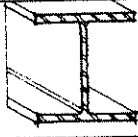
ASTM STANDARD REINFORCING BARS			
Bar size	Nominal dimensions:		Weight per linear foot (lbs.)
	Diameter (inches)	Cross-sectional area (inches ²)	
# 3	.375	.11	.376
# 4	.500	.20	.668
# 5	.625	.31	1.043
# 6	.750	.44	1.502
# 7	.875	.60	2.044
# 8	1.000	.79	2.670
# 9	1.128	1.00	3.400
# 10	1.270	1.27	4.303

12.10 STEEL

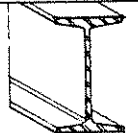


STRUCTURAL STEEL SHAPES

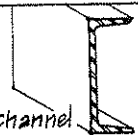
- W shape
Wide flange



- S shape
American standard



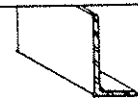
- C shape
American standard channel



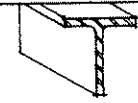
- L shape
Equal leg angle



- L shape
Unequal leg angle



- WT shape
Structural tee
cut from W shape



- Structural tubing
Square or rectangular



- Structural tubing
Circular pipe



- Bars
Square, round, and flat



- Plate



- Lightgauge shapes - See 4.28, 5.42.

- Open web steel joists - See 4.25.

* Refer to the American Institute of Steel Construction (AISC) Manual of Steel Construction for complete listing of sizes and weights.

STEEL is used for light and heavy structural framing as well as a wide range of building products such as windows, doors, hardware, and fastenings. As a structural material, steel combines high strength and stiffness with elasticity. Measured in terms of weight to volume, it is probably the strongest low-cost material available.

Although classified as an incombustible material, steel becomes ductile and loses its strength under high-heat conditions (over 1000°F). When used in buildings that require fire-resistant construction, structural steel must be coated, covered, or enclosed with fire-resistant materials. (See A.12) Since it is normally subject to corrosion, steel must be painted, galvanized, or chemically treated for protection against oxidation.

Most structural steel is medium carbon grade steel, which is available in plate and bar forms, and in the structural shapes illustrated on the left. These shapes may be fastened by welding or mechanical means.

- Carbon steel
 - ASTM A36 is the most common strength grade
 - Yield point = 36,000 psi
- High strength, low alloy steel
 - ASTM A572 most commonly used
 - Yield point = 50,000 psi
 - ASTM A242 and A588 weathering steels have superior corrosion resistance due to a tight oxide coating they form on their surfaces; they may be left exposed.

Steel may be heat-treated or altered with additives to form alloys during its manufacture. Below are some of these alloy elements and the steel properties they modify.

- Aluminum Improves surface hardening.
- Chromium Increases corrosion resistance and hardness.
- Copper Increases strength and corrosion resistance.
- Manganese . . . Promotes hardness and wear resistance.
- Molybdenum . . . Increases corrosion resistance and strength.
- Nickel Increases tensile strength and corrosion resistance.
- Tungsten Improves strength retention at high temperatures.

Other ferrous metals used in building construction include:

- Cast iron
 - High carbon content
 - Brittle but strong in compression
 - Used for piping, grates, and ornamental work
- Wrought iron
 - Extremely low carbon content
 - Corrosion resistant
 - Soft, malleable, and tough
 - Used for grilles, hardware, and ornamental work

Nonferrous metals contain no iron. Aluminum, copper, and lead are nonferrous metals commonly used in building construction.

ALUMINUM is a relatively soft yet strong, lightweight, and workable metal. Its corrosion resistance is due to the transparent film of natural oxide it forms on its surface. This oxide coating can be thickened to increase the aluminum's corrosion resistance by an electrical and chemical process known as anodizing. During the anodizing process, aluminum's naturally light, reflective surface can be dyed a number of warm, bright colors. Enamel or lacquer finishes may also be applied to aluminum.

Aluminum is widely used in extruded and sheet forms for secondary building elements such as windows, doors, roofing, flashing, trim, and hardware. For use in structural framing, high strength aluminum alloys are available in shapes similar to those of structural steel. Aluminum sections may be welded, bonded with adhesives, or mechanically fastened.

Care must be taken to insulate aluminum from contact with other metals to prevent galvanic action. It should also be isolated from alkaline materials such as wet concrete, mortar, and plaster.

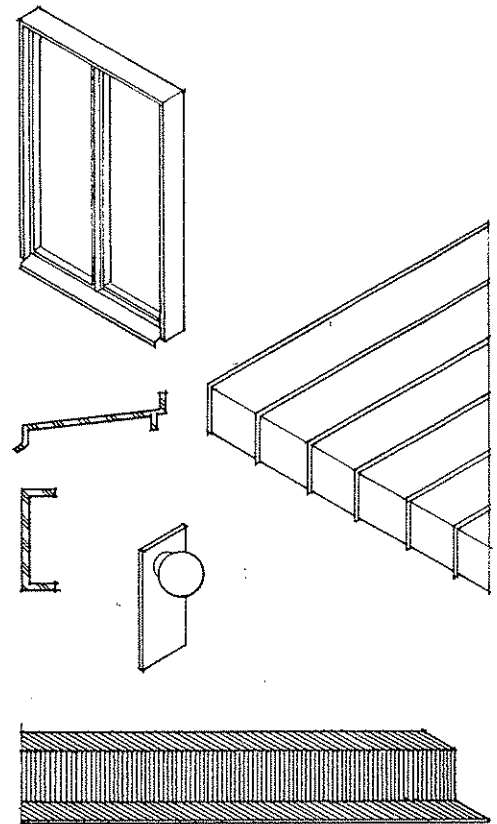
COPPER is used in construction where corrosion resistance, impact resistance, ductility, or high electrical and thermal conductivity is required. Its color and resistance to atmospheric and saltwater corrosion make it an excellent outdoor material. Copper is most commonly used in sheet form for roofing and flashing.

Copper will corrode aluminum, steel, stainless steel, and zinc. It should be fastened, attached, or supported only with copper or carefully selected brass fittings. Contact with red cedar in the presence of moisture (as in wood shingle roofing) will cause premature deterioration of the copper.

BRASS is an alloy of copper and zinc that is used for doors, windows, hardware, and fastenings. It is often termed bronze, as in architectural or statuary bronze.

LEAD is a soft, malleable, corrosion resistant material used for flashing, sound isolation, and radiation shielding. Although lead is the heaviest of the common metals, its pliability makes it desirable for application over uneven surfaces. Lead dust or vapors are toxic.

GALVANIC ACTION can occur between two dissimilar metals when enough moisture is present for electric current to flow. This electric current will tend to corrode one metal while plating the other. The severity of the galvanic action depends on how far apart the two metals are on the galvanic series table.



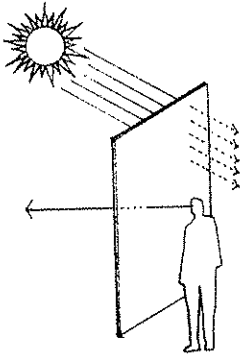
GALVANIC SERIES

Magnesium	+
Zinc	
Aluminum, 1100	
Cadmium	
Aluminum, 2024 T4	
Mild steel	
Cast iron	
Lead	
Tin	
Brass	
Copper	
Monel	
Nickel	
Stainless steel	
Silver	
Gold, platinum	-

Current flows from positive to negative.

The metal that is higher in the table is sacrificial and corrodes.

12.12 GLASS



Glass is a chemically inert, transparent, hard, brittle material. It is used in building construction in various forms. Foamed or cellular glass is used as rigid, vaporproof thermal insulation. Glass fibers are used in textiles and for material reinforcement. In spun form, glass fibers form glass wool which is used for acoustical and thermal insulation. Glass block is used to control light transmission, glare, and solar radiation. Glass, however, is used most commonly to glaze a building's window, sash, and skylight openings.

The three basic types of flat glass are:

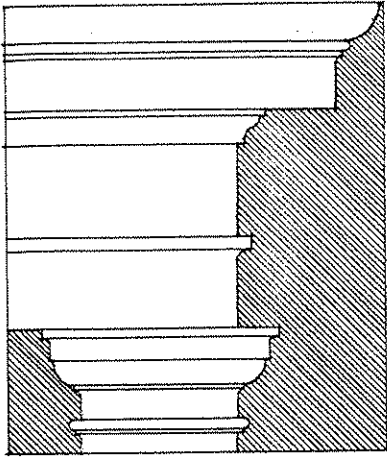
- SHEET GLASS.** ① Molten glass is drawn horizontally or vertically and then annealed. Inherent wave distortion is most noticeable in the larger sizes and thicker sheets; to minimize this distortion, glass should be glazed with the wave running horizontally.
- FLOAT GLASS.** ② Glass is floated on a bed of molten tin and then annealed slowly. Flat, parallel surfaces minimize distortion and eliminate the need for grinding and polishing. Float glass is the most widely used type of flat glass.
- PLATE GLASS.** ③ Glass is rolled, then ground and polished. Plate glass provides virtually clear, undistorted vision.

Variations of the three basic types of glass include:

- Pattern glass.** • Translucent glass with linear or geometric patterns embossed on one or both sides; similar to plate glass but not ground and polished.
- Wire glass.** • Wire mesh or parallel wires are inserted into rolled glass during manufacture; wires hold glass together when cracked by impact or heat; qualifies as a safety glazing material and may be used as a fire resistant material to glaze fire doors and windows.
- Heat-absorbing or tinted glass.** • Tinted glass absorbs solar radiation, reduces heat buildup in a building, and controls glare; tint may be bronze, gray, or blue-green; tint also reduces light transmission.
- Reflective coated glass.** • Transparent metal coating applied to the glass surface reduces the solar energy transmitted into a building; coating may be applied to one surface of single glazing, in between the plies of laminated glass, or to the exterior or interior surfaces of insulating glass.
- Tempered glass.** • Glass is heat-strengthened for increased resistance to impact and thermal stresses; 3 to 5 times stronger than annealed glass; pulverizes into pebble-sized pieces when broken.
- Laminated glass.** • A thin sheet of tough, transparent plastic is laminated between two layers of glass; when broken, glass particles tend to adhere to the plastic sheet; qualifies as a safety glazing material; special types are available that are burglar resistant, bullet resisting, or soundproofing.
- Insulating glass.** • Two layers of glass are separated by a hermetically sealed air space to provide thermal insulation and restrict condensation; glass edge units have a $\frac{3}{16}$ " air space; metal edge units have a $\frac{1}{4}$ " or $\frac{1}{2}$ " air space.

GLASS PRODUCT	TYPE	NOMINAL THICKNESS	MAXIMUM AREA	WEIGHT (lbs./S.F.)	
Window or sheet glass	AA, A, B	SS 3/32" DS 1/8"	60" x 60" 60" x 80"	1.22 1.63	<ul style="list-style-type: none"> • Verify maximum sizes with glass manufacturer. • Any glass 1/8" or thicker can be tempered, except for patterned or wire glass; tempered glass can also be incorporated into insulating or laminated glass units. • Reflective coatings may be applied to float, plate, tempered, laminated, or insulating glass.
Float or plate	Mirror Glazing	1/4" 1/8" 1/4"	75 S.F. 74" x 120" 128" x 204"	3.28 1.64 3.28	
Heavy float or plate	Glazing	5/16" 3/8" 1/2" 5/8" 3/4" 7/8"	124" x 200" 124" x 200" 120" x 200" 120" x 200" 115" x 200" 115" x 200"	4.10 4.92 6.54 8.17 9.18 11.46	
Patterned glass	Various patterns	1/8" 7/32"	60" x 132" 60" x 132"	1.60 2.40	
Wire glass	Polished-mesh Patterned-mesh Parallel wires	1/4" 1/4" 7/32" 1/4" 3/8"	60" x 144" 60" x 144" 54" x 120" 60" x 144" 60" x 144"	3.50 3.50 2.82 3.50 4.45	
Tinted glass	Bronze Gray	1/8" 3/16" 1/4" 3/8" 1/2" 1/8" 3/16" 1/4" 3/8" 1/2"	35 S.F. 120" x 144" 128" x 204" 124" x 200" 120" x 200" 35 S.F. 120" x 144" 128" x 204" 124" x 200" 120" x 200"	1.64 2.45 3.27 4.90 6.54 1.64 2.45 3.27 4.90 6.54	<ul style="list-style-type: none"> • Solar energy transmission reduced 35% to 75%. • Visible light transmission reduced 32% to 72%.
Laminated glass	2 - 1/8" float Heavy float	1/4" 3/8" 1/2" 5/8"	72" x 120" 72" x 120" 72" x 120" 72" x 120"	3.30 4.80 6.35 8.00	
Insulating glass 2 - 3/32" sheets, 2 - 1/8" sheets, 2 - 1/8" DS sheet, plate, or float, 2 - 3/16" plate or float, 2 - 1/4" plate or float,	Glass edge: 3/16" air space 3/16" air space Metal edge: 1/4" air space 1/2" air space 1/4" air space 1/2" air space 1/4" air space 1/2" air space	3/8" 7/16" 1/2" 3/4" 5/8" 7/8" 3/4" 1"	10 S.F. 24 S.F. 22 S.F. 22 S.F. 34 S.F. 42 S.F. 50 S.F. 70 S.F.	2.40 3.20 3.27 3.27 4.90 4.90 6.54 6.54	<ul style="list-style-type: none"> • R-value = 1.61 • R-value = 1.61 • R-value = 1.72 • R-value = 2.04 • R-values for units with 1/2" air space and low emittance coating: e = 0.20, R = 3.13 e = 0.40, R = 2.63 e = 0.60, R = 2.33

12.14 STONE



Stone is an aggregate or combination of minerals, each of which is composed of inorganic chemical substances. To qualify as a construction material, stone should have the following qualities:

- **Strength** Most types of stone have more than adequate compressive strength. A stone's shear strength, however, is usually about 1/10 of its compressive strength.
- **Hardness** Hardness is important when stone is used for flooring, paving, or stairs.
- **Durability** Resistance to the weathering effects of rain, wind, heat, and frost action is necessary for exterior stonework.
- **Workability** A stone's hardness and grain texture must allow it to be quarried, cut, and shaped.
- **Density** A stone's porosity affects its ability to withstand frost action and staining.
- **Appearance** Appearance factors include color, grain, and texture.

Stone may be classified according to geological origin into the following types:

- **Igneous** Cooled molten rock (granite)
- **Sedimentary** . . . Deposited by glacial action (limestone)
- **Metamorphic** . . . Formed under intense pressure and heat (marble, slate)

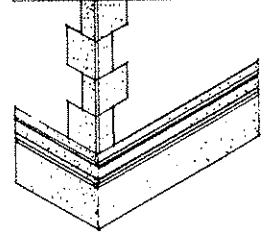
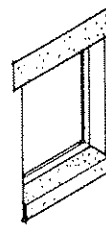
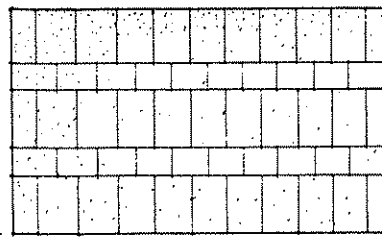
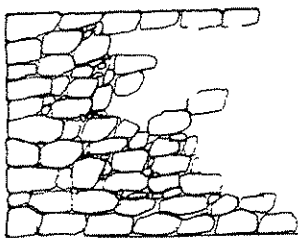
As a loadbearing wall material, stone is similar to modular unit masonry. Although stone masonry is not necessarily uniform in size, it is laid up with mortar and used in compression. Almost all stone is adversely affected by sudden changes in temperature and should not be used where a high degree of fire resistance is required.

Stone is used in construction in the following forms:

- **Rubble** Used primarily as a wall material.
- **Dimension** Cut stone is the most widely used form and has many applications, from wall panels and cornices to flooring.
- **Flagstone** Flat slabs are used for flooring and horizontal surfacing.
- **Crushed rock** Used as aggregate in concrete products.

Types of stonework include:

- **Rubble** Rough, uncut stonework
- **Ashlar** Cut or split stone masonry patterns
- **Trim** Cut stone for copings, cornices, sills, and lintels

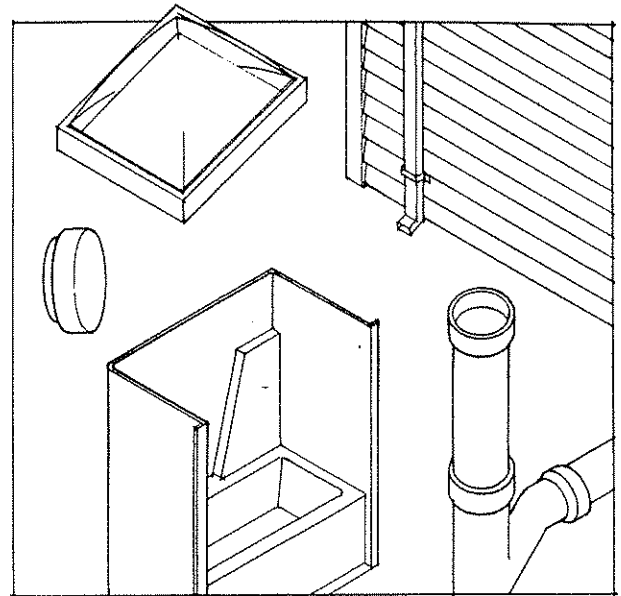


Plastics are synthetic, high polymer materials that are tough, resilient, lightweight, and resistant to corrosion and moisture. Most importantly, they can be formed or molded into a variety of complex shapes. While there are many types of plastics with a wide range of characteristics, they can be divided into two basic categories.

THERMOSETTING plastics go through a pliable stage, but once they are set or cured, they remain rigid and cannot be softened again by reheating.

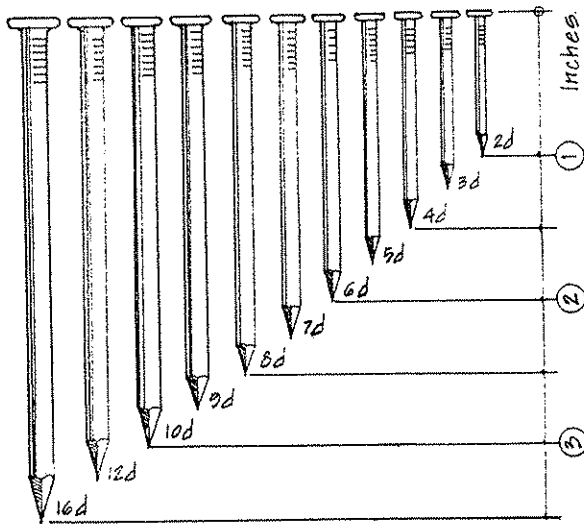
THERMOPLASTIC materials hold their shape at normal temperatures, but at a higher temperature, known as the softening point, they can be molded into a new shape.

In the table below are listed the plastics that are commonly used in construction and their primary uses.



THERMOSETS (Abbreviation)	USES
Epoxies (EP)	Adhesives; coating compounds
Melamines (MF)	High-pressure laminates; adhesives
Phenolics (PF)	Electrical parts; laminates; foamed insulation
Polyesters	Fiberglass-reinforced plastics; bathroom fixtures; window frames
Polyurethanes (UP)	Rigid foam insulation
Silicones (SI)	Brick and masonry waterproofing
THERMOPLASTICS (Abbreviation)	USES
Acrylonitrile-butadiene-styrene (ABS)	Pipe and pipe fittings; door hardware
Acrylics (Polymethylmethacrylate - PMMA)	Glazing; lighting fixtures; roofing; latex paints
Cellulose (Cellulose acetate-butyrate - CAB)	Pipe and pipe fittings; adhesives
Nylons (Polyamides - PA)	Synthetic fibers and filaments; locks, latches, rollers
Polycarbonates (PC)	Safety glazing; lighting fixtures
Polyethylene (PE)	Vapor barriers; pipe; electrical insulation
Polypropylene (PP)	Pipe and pipe fittings; carpeting fiber
Polystyrene (PS)	Lighting fixtures; foamed insulation
Vinyls (Polyvinyl chloride - PVC)	Flooring; siding; gutters; window frames; facings

12.16 NAILS



A nail consists of a metal shaft, pointed at one end, and formed into a head at the other.

Material:

- Nails are usually of mild steel, but may also be of aluminum, copper, brass, zinc, or stainless steel.
- Nails may be coated with zinc, copper, or brass.
- Tempered, high carbon steel nails are used for greater strength in masonry applications.
- The type of metal used should be compatible with the materials being secured to avoid loss of holding power and prevent staining of the materials' surfaces.

Length and diameter of the shank:

- Nail lengths are designated by the term penny (d).
- Nails range in length from 2d (about 1") to 60d (about 6").
- Nails longer than 20d may be referred to as spikes.
- Rule of thumb: Nail length = 3 x thickness of the material being secured.
- Large diameter nails are used for heavy work while lighter nails are used for finish work.
- Thinner nails are used for hardwood than for softwood.

Form of the shank:

- For greater gripping strength, nail shafts may be serrated, barbed, threaded, fluted, or twisted.
- Nail shafts may cement-coated for greater resistance to withdrawal, or be zinc-coated for corrosion resistance.

Nail heads:

- Flat heads provide the largest amount of contact area and are used when exposure of the heads is acceptable.
- The heads of finish nails are only slightly larger than the shaft and may be tapered or cupped.
- Double-headed nails are used for easy removal in temporary construction (e.g., concrete formwork).

Nail points:

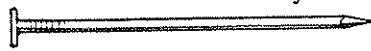
- Most nails have diamond-shaped points.
- Sharp-pointed nails have greater holding strength but may tend to split some woods.
- Blunt points should be used for easily split woods.
- Nails may also have needle, truncated, or chisel points.

Power-driven fasteners:

- Pneumatic nailers and staplers, driven by a compressor, are capable of fastening materials to wood, steel, or concrete.
- Powder-driven fasteners use gunpowder charges to drive a variety of studs into concrete or steel.
- Consult the manufacturer for types of fastenings available and applications.



Common nails • For general construction (2d-60d)



Box nails • For light construction (2d-40d)



Casing nails • For interior trim (2d-40d)



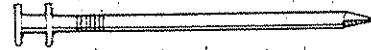
Finishing nails • For cabinetry (2d-20d)



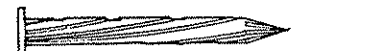
Wire brads • For light work (3/16"-3")



Cut nails • For wood flooring (2d-20d)



Double-headed nails • For temporary construction



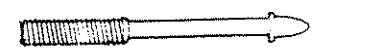
Masonry nails • For concrete and masonry



Drywall nails • For gypsum board



Roofing nails • For roofing; may have washers to seal nail holes.



Power-driven studs • For fastening into concrete or steel

Because of their threaded shafts, screws have greater holding power than nails and are more easily removable. The more threads they have per inch, the greater their gripping strength. Screws are classified by:

- Use Wood, machine, sheet metal, drywall, set screws
- Type of head . . Flat, round, oval, or pan; slotted, Phillips, or hex socket
- Finish Steel, brass, aluminum, bronze, stainless steel
- Lengths $\frac{1}{2}$ " to 6"
- Diameters Up to 24 gauge

A wood screw's length should be about $\frac{1}{8}$ " less than the combined thickness of the boards being joined, with $\frac{1}{2}$ to $\frac{2}{3}$ of the screw's length penetrating the base material. Fine-threaded screws are generally used for hardwoods while coarse-threaded ones are used for softwoods.

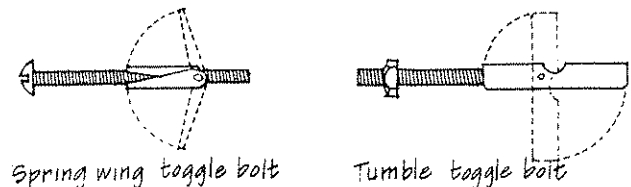
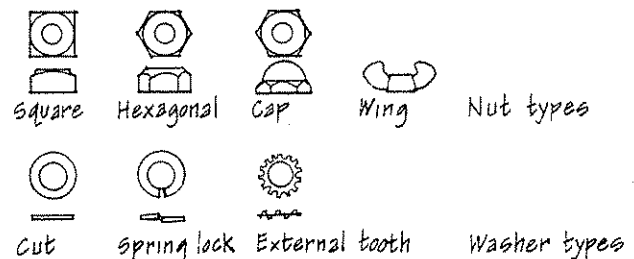
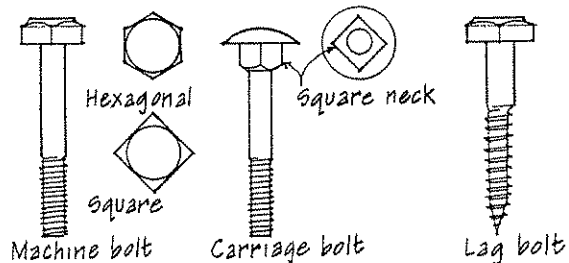
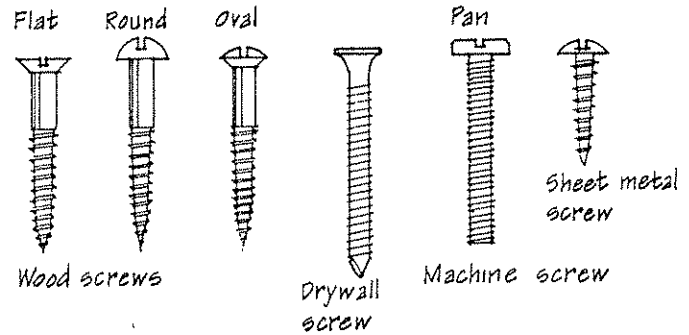
Holes for screws should be predrilled and be equal to the base diameter of the threads. Some screws, such as drywall screws, are self-drilling.

Bolts are round sections of metal, headed at one end and threaded at the other. They are normally used for structural wood or metal connections. Special types are available to anchor plates to masonry or concrete.

- Lengths $\frac{3}{4}$ " to 30"
- Diameters $\frac{1}{4}$ " to $\frac{1}{4}$ "
- Head types . . . Flat, round, oval; square or hexagonal
- Nuts Drilled and threaded to receive threaded end of bolt.
- Washers Used to increase the force-exerting contact area between the head or nut and the material being fastened.
 - May also be used to provide seals, insulate incompatible metals from each other, and act as spacing devices.

- Lag bolts or screws are used when only one end of the bolt is accessible.

- Toggle bolts are used to fasten materials to plaster, gypsum board, and other thin wall materials.



12.18 MISCELLANEOUS FASTENINGS AND ADHESIVES

Expansion shields and anchors

- Used to secure materials to plaster, gypsum board, masonry, or concrete bases.
- Upon the insertion and turning of a screw or bolt, the shield expands in size and exerts pressure on the base material.

Metal framing connectors

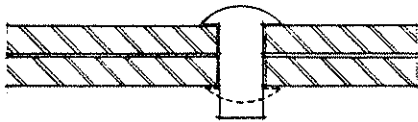
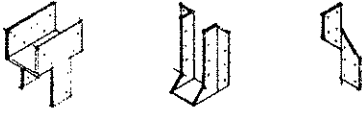
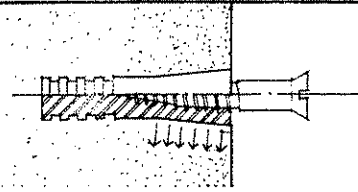
- Used to connect wood framing members to each other or to masonry or concrete supports.
- Typical types include post bases and caps, joist and beam hangers, framing anchors, tension ties, and holdowns.

Timber connectors

- Used to distribute a load over a larger area of the timber in heavy frame construction and trusswork.
- Split ring connectors are used for wood-to-wood connections and shear plates for steel-to-wood connections.

Rivets

- Used to permanently join structural steel members.
- Have been largely superseded by less labor-intensive techniques of bolting or welding.



Adhesives are used to secure the surfaces of two materials together. Numerous types of adhesives are available, many of them being tailor-made for use with specific materials and under specified conditions. They may be supplied in the form of a solid, liquid, powder, or film; some require a catalyst to activate their adhesive properties. Always follow the manufacturer's recommendations in the use of an adhesive.

Important considerations in the selection of an adhesive include:

- **Strength** Adhesives are usually strongest in resisting tensile and shear stresses and weakest in resisting cleavage or splitting stresses.
- **Curing or setting time** Ranges from immediate bonding to curing times of up to several days.
- **Setting temperature range** Some adhesives will set at room temperature while others require baking at elevated temperatures.
- **Method of bonding** Some adhesives bond on contact while others require clamping or higher pressures.
- **Characteristics** Adhesives vary in their resistance to water, heat, sunlight, chemicals, as well as their aging properties.

Common types of adhesives include:

- **Animal or fish glues** Primarily for indoor use where temperature and humidity do not vary greatly; may be weakened by exposure to heat or moisture.
- **White glue** Polyvinyl glue; sets quickly and does not stain; slightly resilient.
- **Epoxy resin** Extremely strong; may be used to secure both porous and nonporous materials; may dissolve some plastics; unlike other adhesives, epoxy glues will set at low temperatures and under wet conditions.
- **Resorcin resin** Strong, waterproof, and durable for outdoor use; flammable; dark color may show through paint.
- **Contact cement** Forms a bond on contact; does not require clamps; generally used to secure large sheet materials such as plastic laminate.

The purpose of a coating is to protect, preserve, or visually enhance the surface to which it is applied. The main types of coatings are paints, varnishes, and stains.

PAINTS are opaque film-forming materials that consist of pigments, binders, and solvents.

VARNISHES contain no pigments and form clear or transparent coatings.

STAINS penetrate and impart color to wood surfaces without obscuring the natural wood grain; some are pigmented and approach paint's film-forming properties.

Considerations in the selection of a coating include:

- Compatibility of the coating with the surface to which it is applied.
- The surface preparation and priming required.
- The method of application and drying time required.
- Conditions of use and the required resistance to water, heat, sunlight, temperature variations, mildew, chemicals, and physical abrasion.

The table below lists the basic types of paints and coatings according to surface material and finish. The listing is adapted from recommendations of the National Paint and Coatings Association. Always follow the manufacturer's recommendations in the application of a paint or other protective coating.

PRIMERS AND SEALERS		FINISH COATS	
Interior surfaces	Exterior surfaces	Interior surfaces	Exterior surfaces
<u>Walls</u> <ul style="list-style-type: none"> • Latex • Alkyd • Oil base • Alkali resistant 	<u>Wood</u> <ul style="list-style-type: none"> • Oil base • Oleoresinous <u>Metal</u> <ul style="list-style-type: none"> • Oil base <ul style="list-style-type: none"> • Red lead* • Zinc chromate • Alkyd base <ul style="list-style-type: none"> • Red lead* • Zinc chromate • Zinc oxide • Latex inhibitive • Wash primers • Portland cement paints 	<u>Gloss finishes</u> <ul style="list-style-type: none"> • Wall paints • Enamels • Floor enamels <ul style="list-style-type: none"> • Alkyd • Epoxy • Urethane • Clear finishes <ul style="list-style-type: none"> • Floor and trim varnishes • Shellac <u>Semi-gloss finishes</u> <ul style="list-style-type: none"> • Wall paints • Enamels • Latex paints • Clear finishes <ul style="list-style-type: none"> • Flat varnishes • Penetrating sealers <u>Flat finishes</u> <ul style="list-style-type: none"> • Alkyd wall paints • Latex wall paints • Fire-retardant paints <u>Miscellaneous finishes</u> <ul style="list-style-type: none"> • Pigmented stains • Dye-type stains 	<u>Oil base finishes</u> <ul style="list-style-type: none"> • Gloss house paints • Barn paints • Shingle stains <u>Oleoresinous finishes</u> <ul style="list-style-type: none"> • Trim enamels • Metal paints <u>Alkyd enamels</u> <ul style="list-style-type: none"> • Trim enamels • Masonry paints <u>Latex finishes</u> <ul style="list-style-type: none"> • Latex house paints • Masonry paints <u>Miscellaneous coatings</u> <ul style="list-style-type: none"> • Zone-marking paints • Aluminum paints <ul style="list-style-type: none"> • Heat-resistant paint • Roof coatings • Clear wood finishes • Alkali resistant finishes • Roof coatings <ul style="list-style-type: none"> • Bituminous • Latex • Portland cement powder paints

* Lead is toxic and its use is restricted to nonresidential applications.

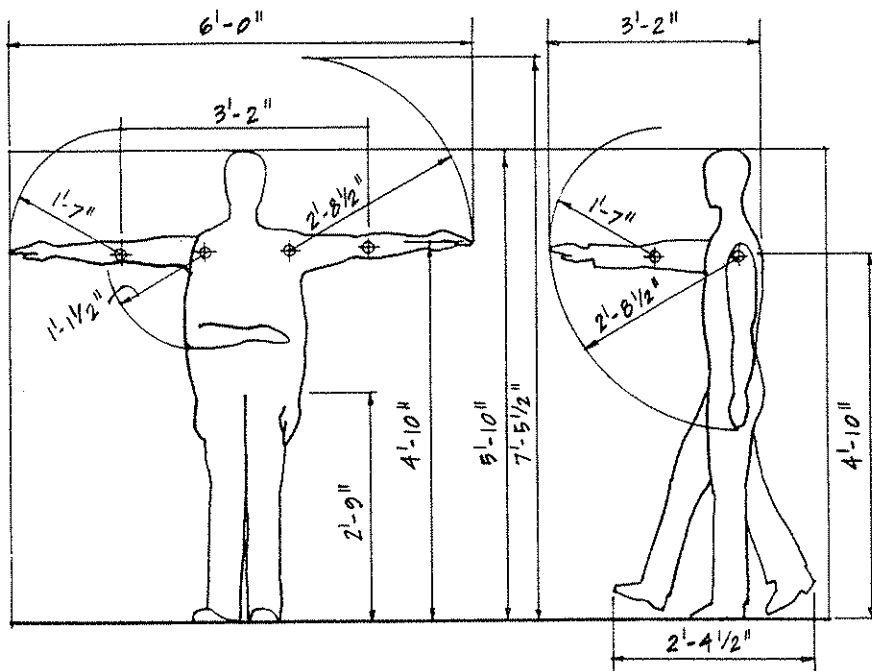
All materials to receive paint or other coating must be properly prepared and primed to ensure adhesion of the coating to their surfaces and to maximize the life of the coating. In general, surfaces should be dry and free of contaminants, such as dirt, grease, moisture, and mildew. The following are recommendations for various materials.

- Aluminum Any corrosion should be removed by wire brushing.
Any oil or other foreign matter should be removed with solvents or by steam cleaning.
Unweathered aluminum may require a surface-etching treatment before painting.
Prime with a zinc chromate coating.
- Brick Dirt, loose mortar, efflorescence, or other foreign matter should be removed by wire brushing, air pressure, or steam cleaning.
Brick should weather for a month before finishing.
Brick may be sealed with a latex primer or a clear silicone water-repellent.
- Concrete Surface should be free of dirt, excess mortar, form oils, or curing compounds.
Concrete should weather for a month before coating.
Porous surfaces may require a block filler or cement grout primer.
Grouted or chalky surfaces may require an alkali-resistant primer.
Concrete may also be sealed with a clear silicone water-repellent.
- Concrete block Block should be free of dirt, loose or excess mortar, and be thoroughly dry.
Porous surfaces may require a block filler or cement grout primer if the acoustical value of a rough surface is not important.
- Concrete floors Floor should be free of dirt, wax, grease and oils, and should be etched with a muriatic acid solution to improve adhesion of the coating.
Prime with an alkali-resistant coating.
- Galvanized iron All grease, residue, and corrosion should be removed with solvent or chemical washes.
Surface may be primed with a zinc oxide or portland cement paint.
If weathered, galvanized iron should be treated as a ferrous metal.
- Gypsum board Surface should be clean and dry.
Use a latex primer-sealer to avoid raising the fibers of the paper surface.
- Old paint surfaces Surface should be clean, dry, and roughened by sanding or washing with a detergent solution.
- Plaster and stucco Plaster and stucco should be allowed to dry thoroughly and be completely cured.
Soft surfaces should be treated to provide a hard, paintable surface.
Fresh plaster should be primed with an alkali-resistant coating.
- Steel Surface should be free of rust, metal burrs, and foreign matter.
Surface may be cleaned with solvents or by wire brushing, sandblasting, flame cleaning, or pickling with acids.
- Wood Wood should be clean, dry, well-seasoned lumber.
Knots and pitch stains should be sanded and sealed before priming.
Surfaces to be painted should be primed or sealed to stabilize the moisture content of the wood and prevent the absorption of succeeding coats; stains and some paints may be self-priming.
All nail holes, cracks, and other small holes should be filled after the full prime coat.

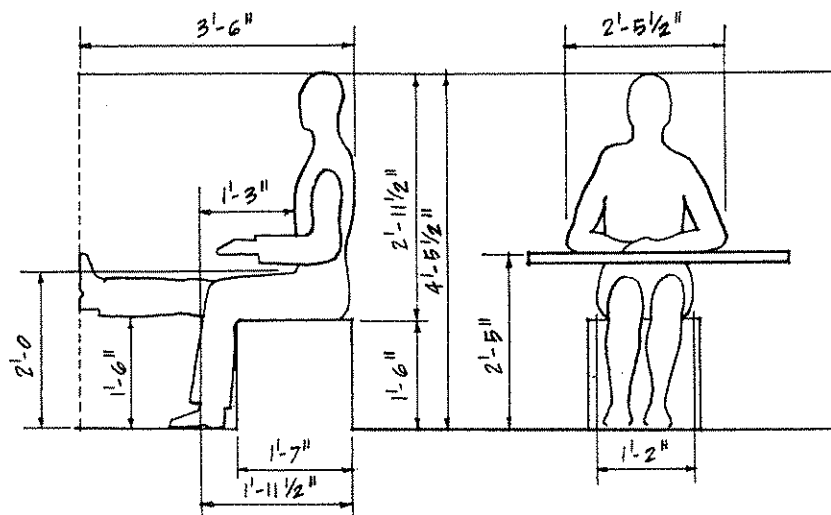
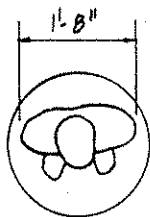
APPENDIX

• Human dimensions	A . 2
• Planning for the handicapped	A . 3
• Furniture dimensions	A . 4
• Building live loads	A . 6
• Weights of materials	A . 6
• Metric conversion factors	A . 8
• Means of egress	A . 10
• Types of construction	A . 11
• Fire-rated construction	A . 12
• Acoustics	A . 14
• Sound control	A . 15
• Sound isolation	A . 16
• CSI Masterformat	A . 17
• Trade associations	A . 20
• Graphic material symbols	A . 22

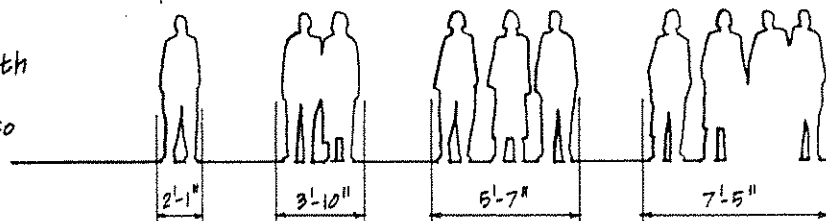
A.2 HUMAN DIMENSIONS



Caution should always be exercised when using a set of dimensional tables or illustrations such as these. These are based on average measurements which may have to be adjusted to satisfy specific user needs. Variations from the norm will always exist due to the differences between men and women, among various age and racial groups, and from one individual to the next.

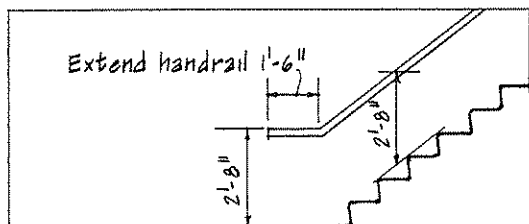
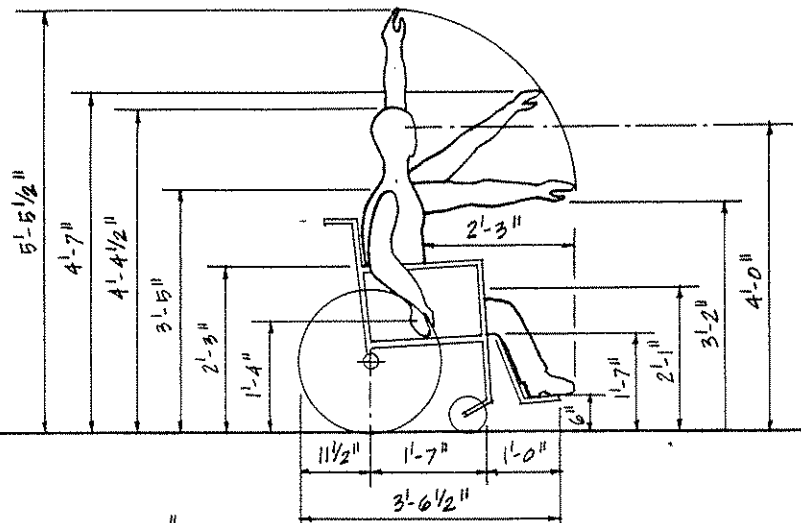


Our body dimensions, and the way we move through and perceive space, are prime determinants of a building's scale, proportions, and spatial layout. It should be noted that there is a difference between the structural dimensions of our bodies and those dimensional requirements that result from how we reach for something on a shelf, sit down at a table, walk down a stairway, or interact with other people. These functional dimensions will vary according to the nature of our activity and the social situation.

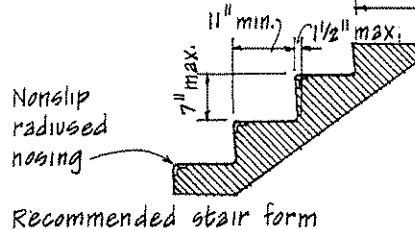


Planning for the handicapped involves the design of facilities that are:

- Accessible to those confined to a wheelchair and the ambulatory:
 - Avoid changes in level and the use of stairs.
 - Use ramps only where necessary
- Identifiable to the blind:
 - Use raised lettering, audible warning signals, and textured surfaces to indicate stairs or hazardous openings.
- Usable:
 - Circulation spaces should be adequate for comfortable movement.
 - All public facilities should have fixtures designed for use by the handicapped.

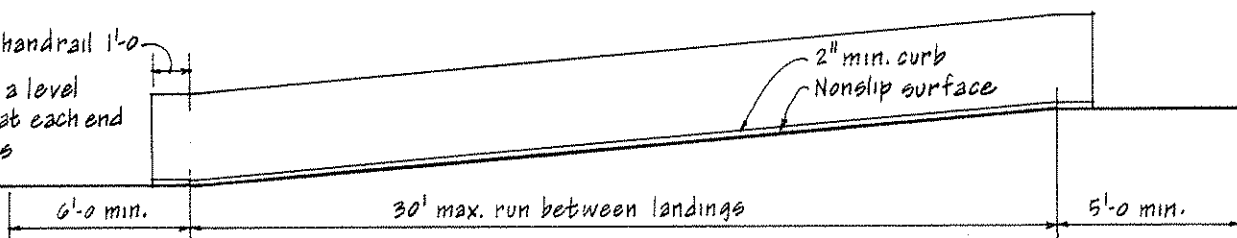


STAIRS

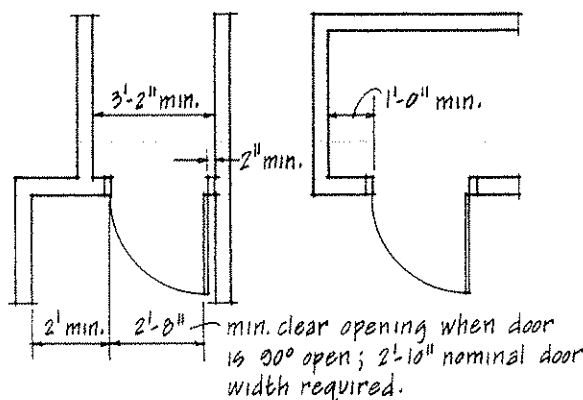


Open risers and projecting nosings are not acceptable for persons on crutches.

Extend handrail 1'-0"
Provide a level landing at each end of ramps



RAMPS



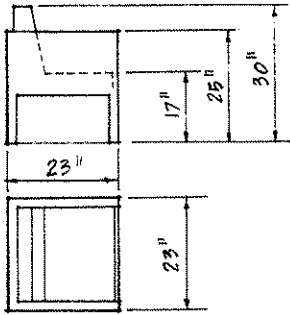
Thresholds should be flush if possible.

2'-6" min. clear for one leaf of double doors.

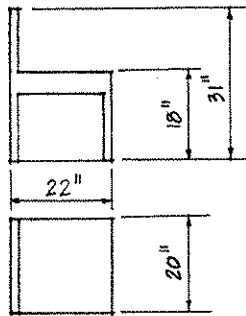
DOORWAYS

Doors should open into the larger space.

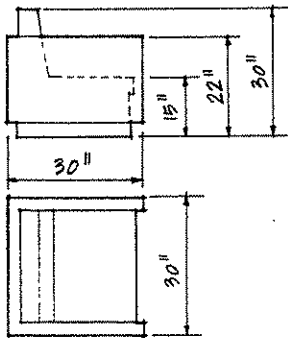
A.4 FURNITURE DIMENSIONS



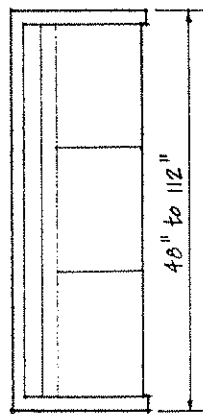
ARM CHAIR



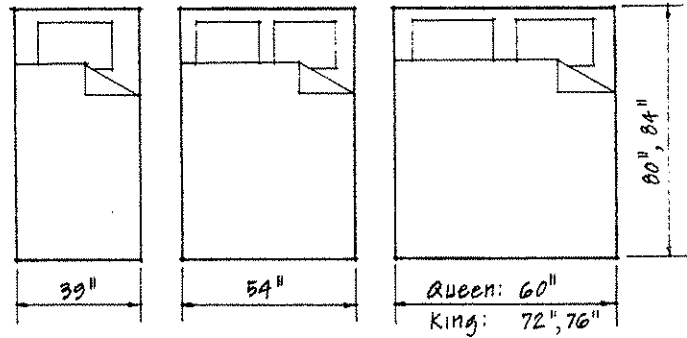
SIDE CHAIR



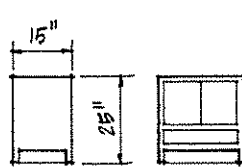
LOUNGE CHAIR



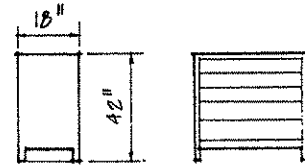
SOFA



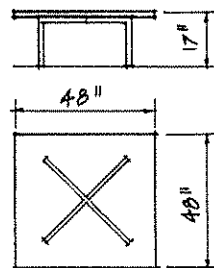
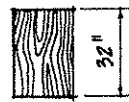
BEDS



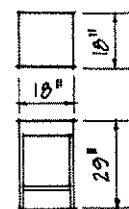
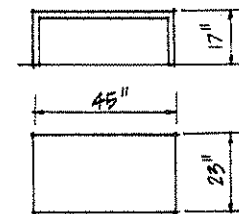
NIGHT TABLE



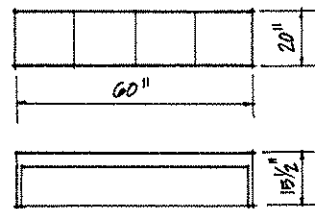
HIGH CHEST



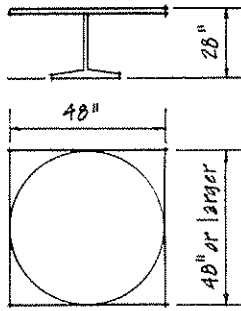
LOW TABLES



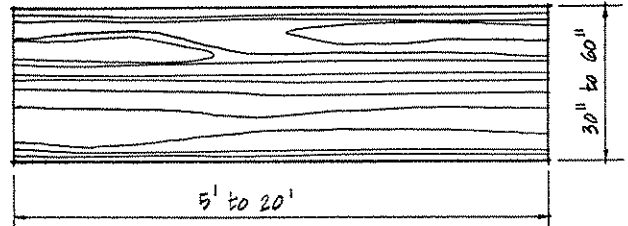
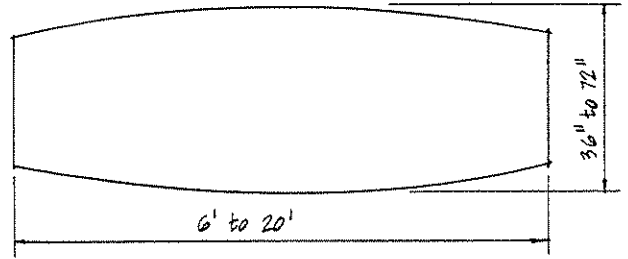
STOOL



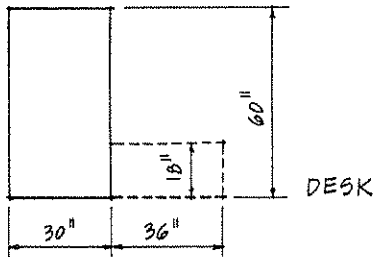
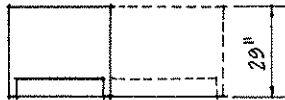
BENCH



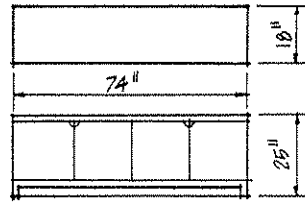
DINING TABLE



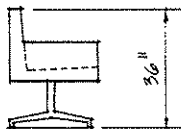
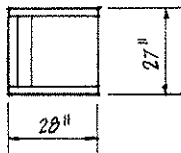
CONFERENCE TABLES



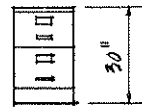
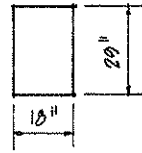
DESK



CREDENZA

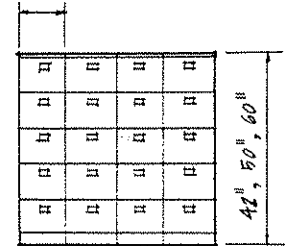


SWIVEL CHAIR



FILE CABINETS

Letter size - 15"
Legal size - 18"



All dimensions are typical. Verify with manufacturer.

Furniture may • Serve as space-defining elements
• Define circulation paths
• Be built-in or set as objects in space.

Selection factors include function, comfort, scale, color, and style.

A.6

BUILDING LIVE LOADS

• WEIGHTS OF MATERIALS

MINIMUM UNIFORMLY DISTRIBUTED
LIVE LOADS (lbs./s.f.)

ASSEMBLY FACILITIES

Theaters with fixed seats	60
Auditoriums and gyms w/ movable seats ...	100
Corridors and lobbies	100
Stages	150

LIBRARIES

Reading rooms	60
Book stacks	150

MANUFACTURING FACILITIES

OFFICES

Office spaces	80
Lobbies	100

RESIDENTIAL FACILITIES

Private dwellings, apartment units, and hotel rooms	40
Public rooms	100
Corridors	60

SCHOOLS

Classrooms	40
Corridors	100

SIDEWALKS AND VEHICULAR DRIVES

STAIRS, FIRE ESCAPES, EXITWAYS

STORAGE WAREHOUSES

Light	125
Heavy	250

STORES

Retail: first floor	100
upper floors	75
Wholesale	125

ROOF LOADS

Minimum, not including wind or seismic loads	20
Roof gardens	100

In the design of a building, the assumed live loads should be the maximum expected to be produced by the intended use or expectancy. In some instances, such as with parking garages, concentrated loads will take precedence.

Always verify the live load requirements with the local building code.

AVERAGE WEIGHTS OF
MATERIALS (lbs./c.f.)

SOIL, SAND AND GRAVEL

Cinder	45
Clay, damp	110
Clay, dry	63
Earth, dry and loose	76
Earth, moist and packed	96
Sand and gravel, dry and loose	105
Sand and gravel, wet	120

WOOD

Cedar	22
Douglas fir	32
Hemlock	29
Maple	42
Oak, red	41
Oak, white	46
Pine, southern	29
Redwood	26
Spruce	27

METAL

Aluminum	165
Brass, red	546
Bronze, statuary	509
Copper	556
Iron, cast	450
Iron, wrought	485
Lead	710
Nickel	565
Stainless steel	510
Steel, rolled	490
Tin	459
Zinc	440

CONCRETE

Stone, plain	144
Stone, reinforced	150
Cinder	100
Lightweight: Expanded shale	105
Perlite	35-50

STONE

Granite	175
Limestone	165
Marble	165
Sandstone	147
Slate	175

Water

Maximum density @ 4°C	62
Ice	56
Snow	8

AVERAGE WEIGHTS OF MATERIALS (lbs./s.f.)

FLOOR AND ROOF CONSTRUCTION

Concrete, reinforced, per inch	
Stone	12.5
Lightweight	6-10
Concrete, plain, per inch	
Stone	12
Lightweight	3-9
Concrete, precast	
6" hollow core, stone	40
6" hollow core, lightweight	30
2" cinder concrete plank	15
2" gypsum plank	12
Steel deck	2-4

FLOOR FINISHES

Cement finish, 1"	12
Marble	30
Terrazzo, 1"	13
Wood, Hardwood 25/32"	4
Softwood 3/4"	2.5
Wood block 3"	15
Vinyl tile	1.33

CEILINGS

Acoustical tile, 3/4"	1
Acoustic plaster on gypsum lath	10
Channel suspended system	1

ROOFING

Built-up, 5-ply felt and gravel	6
Copper or tin	2
Corrugated iron	2
Corrugated fiberglass	0.5
Monel metal	1.5
Shingles, Fiberglass	3
Slate	10
Wood	2
Tile, Concrete	16
Clay	14

WALLS AND PARTITIONS

Brick, per 4" of thickness	35
Concrete masonry units	
Stone or gravel aggregate, 4"	34
6"	50
8"	58
12"	90
Lightweight aggregate, 4"	22
6"	31
8"	38
12"	55
Glass block, 4"	10
Gypsum board, 1/2"	2
Metal lath	0.5
Metal studs with gypsum board	6
Plaster, 1"	
Cement	10
Gypsum	5
Plywood, 1/2"	1.5
Stone, Granite, 4"	59
Limestone, 6"	55
Marble, 1"	13
Sandstone, 4"	40
Slate, 1"	14
Tile, Ceramic	2.5
Glazed wall tile	3
Tile, Structural clay, 4"	18
6"	28
8"	34
Wood studs, 2x4, with	
Gypsum board both sides	8

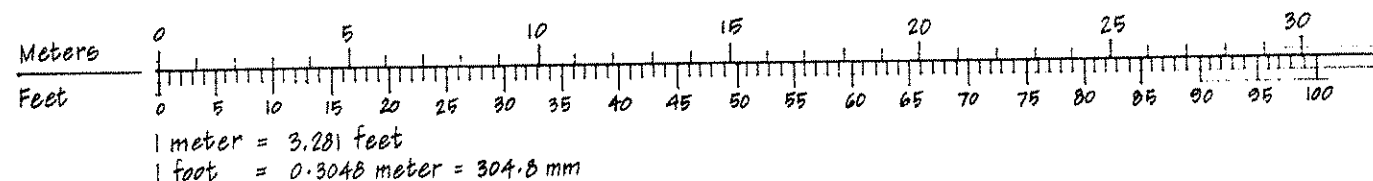
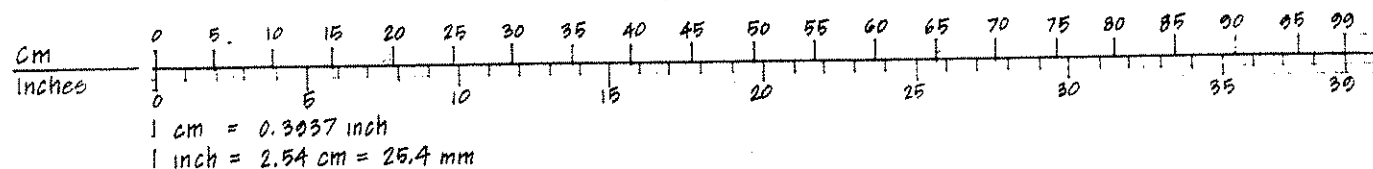
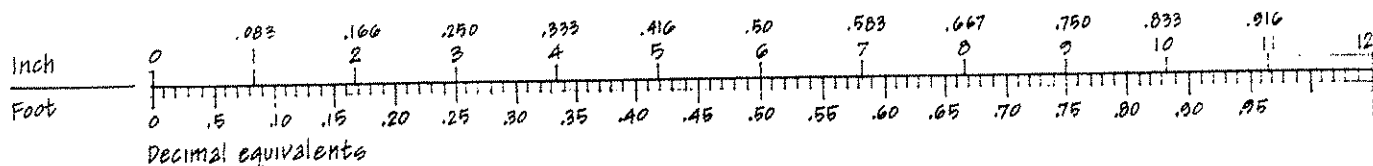
INSULATION

Batt or blanket, per inch	0.3
Fiberboard	2
Foamed board, per inch	0.2
Loose	0.5
Poured in place	2
Rigid	0.8

GLASS

Insulating glass, 1/8" plate	3.25
Polished plate, 1/4"	3.30
Sheet, DS 1/8"	1.60
HS 1/4"	3.25
Wire glass, 1/4"	3.50

A.8 METRIC CONVERSION FACTORS



FACTOR

MULTIPLES • SUBMULTIPLES • PREFIXES • SYMBOLS

Thousand million	10^9	Giga	G
One million	10^6	Mega	M
One thousand	10^3	Kilo	k
One hundred	10^2	Hecto	h
Ten	10^1	Deca	da
One-tenth	10^{-1}	Deci	d
One-hundredth	10^{-2}	Centi	c
One-thousandth	10^{-3}	Milli	m
One-millionth	10^{-6}	Micro	u

MEASUREMENT TYPE	IMPERIAL UNIT	METRIC UNIT	SYMBOL	CONVERSION FACTOR
LENGTH	mile	kilometer	km	1 mile = 1.609 km
	yard	meter	m	1 yard = 0.9144 m = 914.4 mm
	foot	meter	m	1 foot = 0.3048 m
		millimeter	mm	= 304.8 mm
	inch	millimeter	mm	1 inch = 25.4 mm
AREA	square mile	sq. kilometer	km ²	1 mile ² = 2.590 km ²
		hectare	ha	= 259.0 ha (1 ha = 10,000 m ²)
	acre	hectare	ha	1 acre = 0.4047 ha
		square meter	m ²	= 4046.9 m ²
	square yard	square meter	m ²	1 yard ² = 0.8361 m ²
	square foot	square meter	m ²	1 foot ² = 0.0929 m ²
		sq. centimeter	cm ²	= 929.03 cm ²
VOLUME		sq. centimeter	cm ²	1 inch ² = 6.452 cm ² = 645.2 mm ²
	cubic yard	cubic meter	m ³	1 yard ³ = 0.7646 m ³
	cubic foot	cubic meter	m ³	1 foot ³ = 0.02832 m ³
		liter	liter	= 28.32 liters (1000 liters = 1 m ³)
		cubic decimeter	dm ³	= 28.32 dm ³ (1 liter = 1 dm ³)
	cubic inch	cubic millimeter	mm ³	1 inch ³ = 16390 mm ³
		cubic centimeter	cm ³	= 16.39 cm ³
		milliliter	ml	= 16.39 ml
		liter	liter	= 0.01639 liter

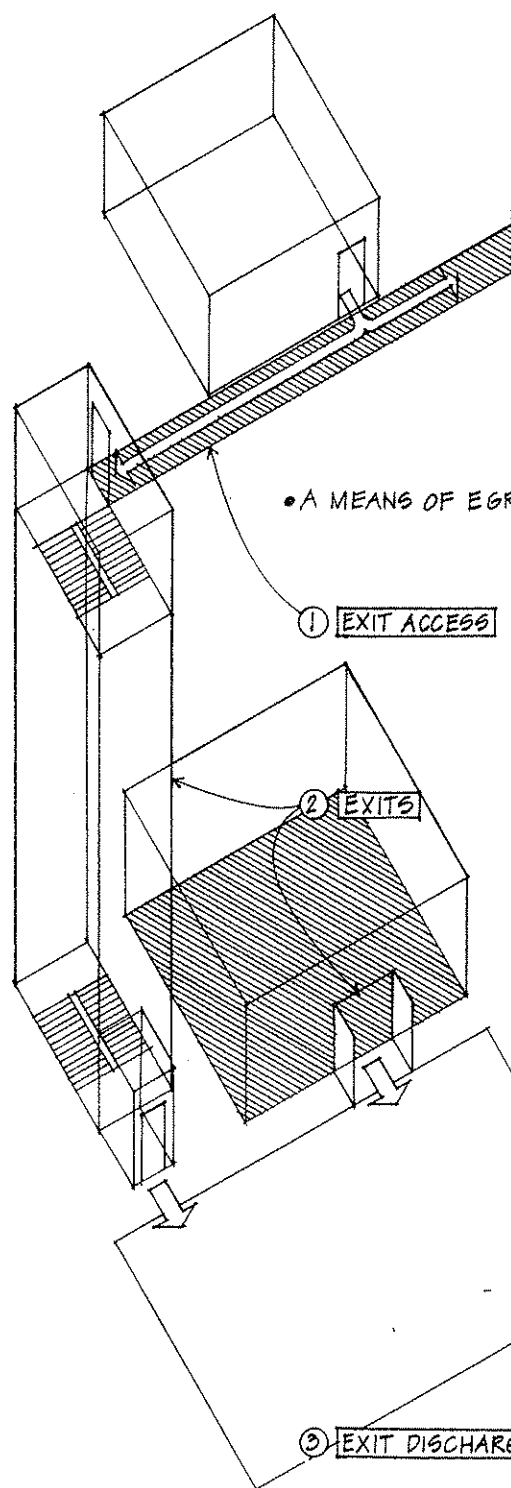
MEASURE TYPE	IMPERIAL UNIT	METRIC UNIT	SYMBOL	CONVERSION FACTOR
MASS	ton kip (1000 lbs.) pound ounce	kilogram kilogram kilogram gram	kg kg kg g	1 ton = 1016.05 kg 1 kip = 453.59 kg 1 lb. = 0.4536 kg 1 oz. = 28.35 g
CAPACITY	quart pint fluid ounce	liter liter cubic centimeter	liter liter cm ³	1 qt. = 1.137 liter 1 pt. = 0.568 liter 1 fl. oz. = 28.413 cm ³
MASS PER UNIT AREA	pound/sq. ft. pound/sq. in. ounce/sq. ft.	kilogram/square meter kilogram/square meter gram/square meter	kg/m ² kg/m ² g/m ²	1 psf = 4.882 kg/m ² 1 psi = 703.07 kg/m ² 1 oz./ft ² = 305.15 g/m ²
DENSITY	pound/cubic foot pound/cubic inch	kilogram/cubic meter gram/cubic centimeter megagram/cubic meter	kg/m ³ g/cm ³ Mg/m ³	1 lb./ft. ³ = 16.02 kg/m ³ 1 lb./in. ³ = 27.68 g/cm ³ 27.68 Mg/m ³
VOLUME RATE OF FLOW	cu. ft./minute cu. ft./second cu. in./second gallon/hour gallon/minute gallon/second	liter/second cubic meter/second milliliter/second liter/hour liter/second liter/second	liter/s m ³ /s ml/s liter/h liter/s liter/s	1 ft ³ /min. = 0.4731 liter/s 1 ft ³ /sec. = 0.02832 m ³ /s 1 in. ³ /sec. = 16.39 ml/s 1 gal./hr. = 4.5461 liter/h 1 gal./min. = 0.07577 liter/s 1 gal./sec. = 4.5461 liter/s
FUEL CAPACITY	gallon/mile miles/mile	liter/kilometer kilometers/liter	liter/km km/liter	1 gpm = 2.825 liter/km 1 mpg = 0.354 km/liter
VELOCITY	miles/hour feet/minute feet/second inch/second	kilometer/hour meter/minute meter/second millimeter/second	km/h m/min m/s mm/s	1 mph = 1.609 km/h 1 fpm = 0.3048 m/min. 1 fps = 0.3048 m/s 1 in./sec. = 25.4 mm/s
TEMPERATURE	° Fahrenheit	degree Celsius	°C	t °C = 0.5556 (t °F - 32)
• Temperature interval	° Fahrenheit	degree Celsius	°C	= 5/9 (t °F - 32) 1 degree F = 0.5556 degree C
HEAT	British thermal unit (Btu)	joule kilojoule	J kJ	1 Btu = 1055 J 1 Btu = 1.055 kJ
• Heat flow rate	Btu/hour	watt kilowatt	W kW	1 Btu/hr. = 0.2931 W 1 Btu/hr. = 0.0002931 kW
• Density of heat flow rate	Btu/ft ² ·hour	watt/square meter	W/m ²	1 Btu/ft ² ·hr = 3.155 W/m ²
• Thermal conductivity	Btu·inch/ft ² ·hour·deg F	watt/meter·deg C	W/m °C	1 Btu·in./ft ² ·hr. °F = 0.1442 W/m °C
• Thermal conductance	Btu/ft ² ·hr·deg F	watt/meter ² ·deg C	W/m ² °C	1 Btu/ft ² ·hr. °F = 5.678 W/m ² °C
• Refrigeration	ton	watt	W	1 ton = 3513 W
POWER	horsepower	watt kilowatt	W kW	1 hp = 745.7 W = 0.7457 kW
LIGHTING	footcandle lumen/sq. foot	lux lux	lux lux	1 ft. candle = 10.76 lux (1 lux = 1 lumen/ft. ²) 1 lumen/ft. ² = 10.76 lux

A.10 MEANS OF EGRESS

Building codes specify:

- The required means of egress for a building's occupants in case of a fire.
- The fire-resistance ratings of materials and construction required for a building depending on its:
 - location (fire district)
 - use and occupancy
 - size (height and area per floor)
- The fire alarm, sprinkler, and other protection systems required for certain uses and occupancies.

These requirements are intended to control the spread of fire and to allow sufficient time for the occupants of a burning building to exit safely before the structure weakens to the extent that it becomes dangerous. The following outlines the principles involved in fire protection. Consult the local applicable code in force for specific requirements.



• A MEANS OF EGRESS must provide safe and adequate access to protected exits leading to a place of refuge. Thus, there are three components to an egress system:

① EXIT ACCESS

- The path or passageway leading to an exit should be as direct as possible, be unobstructed with projections such as open doors, and be well lit; emergency power for lights and exit signs may be required.
- Exits and exit paths should be clearly marked.

② EXITS

- An exit must provide a protected means of evacuation from an exit access to a safe discharge point.
- Exit passageways and stairways must be of 2-hour construction with self-closing doors that are rated at 1½ hours.
- For most occupancies, a minimum of two exits is required to provide a margin of safety in case one exit is blocked.
- Exits should be located as remote from each other as possible without creating dead-end passageways.
- The maximum travel distance from the most remote on a floor to the nearest exit is specified by code according to a building's use, occupancy, and degree of fire hazard.
- The required width of an exit is based on a building's use and occupant load. It is usually specified as the number of persons allowed per unit of width (usually 22"). Examples:

Places of assembly	100
Offices, schools, stores . .	60
Residential buildings . . .	45

③ EXIT DISCHARGE

- See 9.5 for stairway dimensions and requirements.
- In tall buildings, one or more of the exit stairways may be required to be placed in a smokeproof enclosure.
- All exits must discharge to a safe place of refuge outside of the building at ground level.
- In some cases, a protected passageway or foyer may connect an exit stairway to the outside.

TYPES OF CONSTRUCTION

Building codes classify buildings into types of construction which represent varying degrees of resistance to fire. (See table below.)

A building's maximum height and area per floor will be limited by its construction type as well as its use, occupancy, and location. In some cases, this size limitation may be exceeded if the building is equipped with a fire sprinkler system, or if it is divided with fire walls into areas not exceeding the size limitation.

Fire walls must have a fire rating of 2 to 4 hours and extend from the building's foundation through the roof to a parapet or to the underside of a noncombustible roof. Openings in fire walls are restricted in size and must be protected by self-closing fire doors, fire-rated window assemblies, or ducts equipped with fire dampers.

The table below outlines the required fire-resistive ratings of building elements for the various types of construction. Consult the local applicable code to confirm these requirements and the building use groups listed on the right. On the following two pages are illustrated representative construction assemblies and their fire ratings.

EXAMPLES OF BUILDING USE GROUPS

- (A) Assembly
Auditoriums, theaters, stadiums
- (B) Business
Offices, retail shops, restaurants
- (E) Educational
Schools, day-care facilities
- (F) Factories
Manufacturing plants, mills
- (H) Hazardous uses
Facilities handling flammable or explosive materials
- (I) Institutional
Hospitals, nursing homes, reformatories
- (R) Residential
Homes, apartment buildings, hotels
- (S) Storage
Warehousing facilities

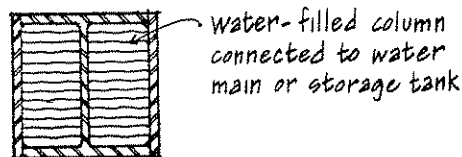
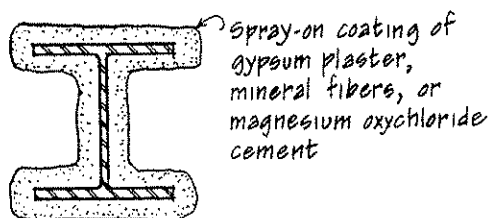
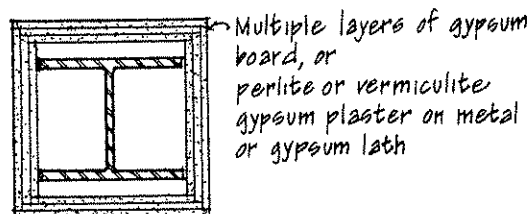
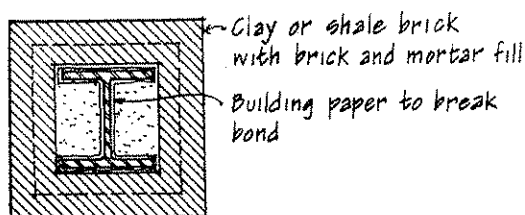
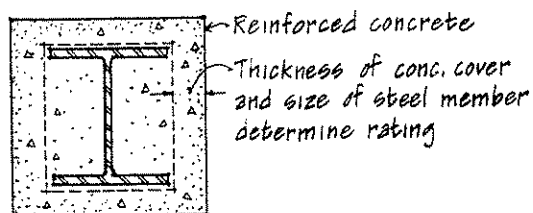
FIRE-RESISTIVE REQUIREMENTS (in hours)

BUILDING ELEMENT	NONCOMBUSTIBLE				COMBUSTIBLE			
	Type I	Type II			Type III	Type IV	Type V	
	Fire-resistive	Fire-resistive	1-hour	No requirement	1-hour	Heavy timber	1-hour	No requirement
Structural frame	3-4	2	1	None	1	1 or H.T.	1	None
Floors	2	2	1	None	1	H.T.	1	None
Interior bearing walls	3-4	2	1	None	1	1	1	None
Exterior walls, windows, doors	Varies with distance from property line and adjacent structures							
Roofs	0-2	0-1	0-1	None	1	H.T.	1	None
Permanent partitions	1	1	1	None	1	1 or H.T.	1	None
Fire walls	2-4	2-4	2-4	2-4	2-4	2-4	2-4	2-4
Exit and stairway enclosures	2	2	2	2	2	2	2	2
Shaft enclosures	2	2	1	1	1	1	1	0-1

A.12 FIRE-RATED CONSTRUCTION

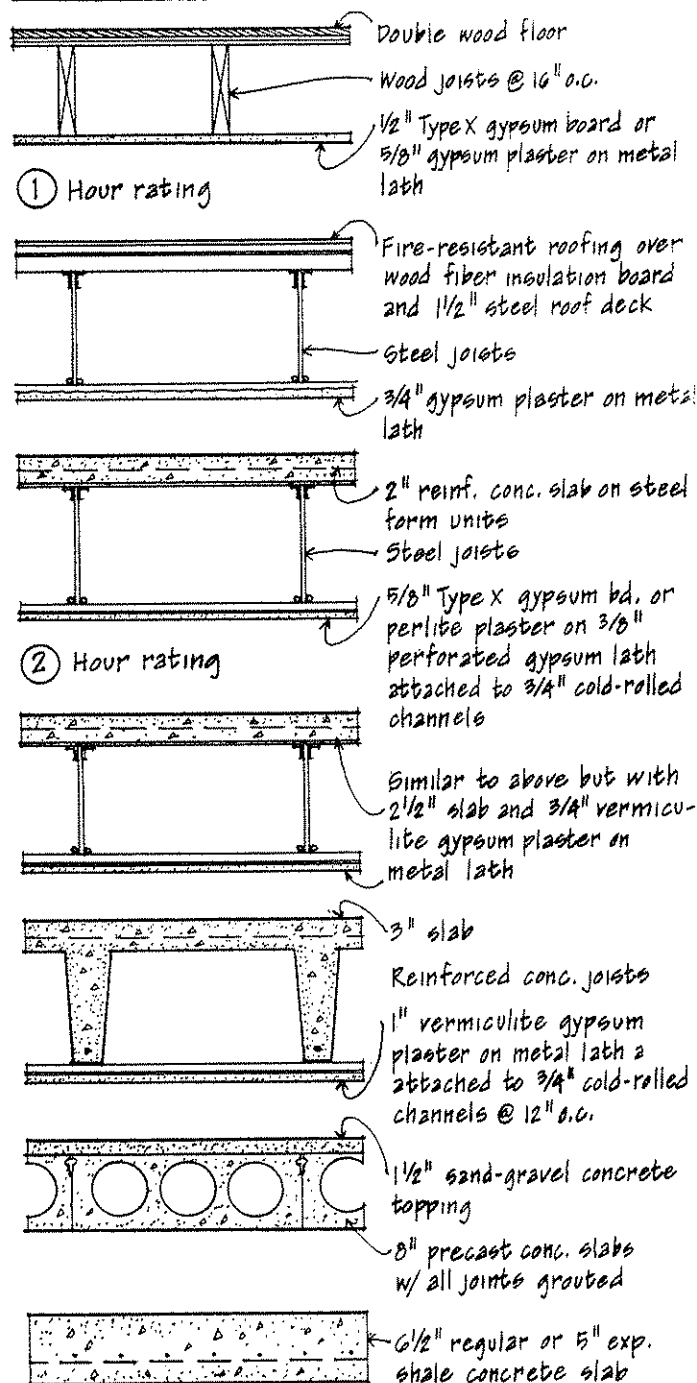
Fire-resistant construction is rated according to the length of time a material or assembly can be exposed to fire without sustaining significant damage. Fire-resistant construction therefore involves both reducing a material's flammability and controlling the spread of fire.

On this and the facing page is a sampling of fire-resistance ratings for various construction assemblies. For more detailed specifications, consult the Underwriters' Laboratories, Inc. Materials List, or the governing building code.



Because structural steel can be weakened by the high temperatures of a fire, it requires protection to qualify for certain types of construction.

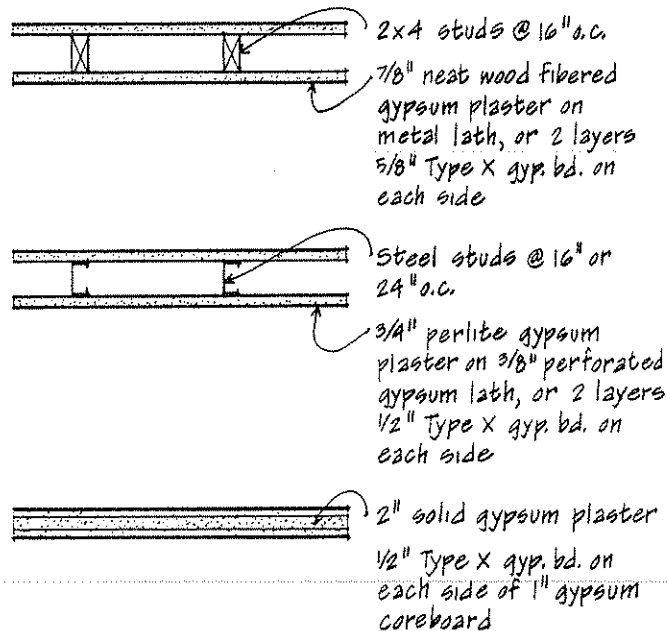
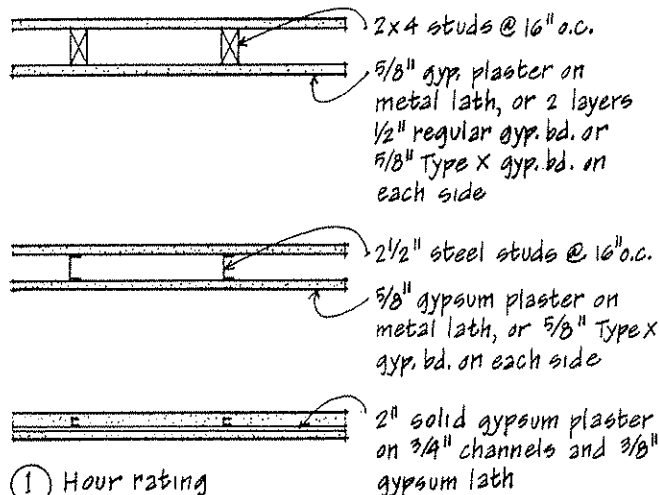
FIRE PROTECTION FOR STRUCTURAL STEEL



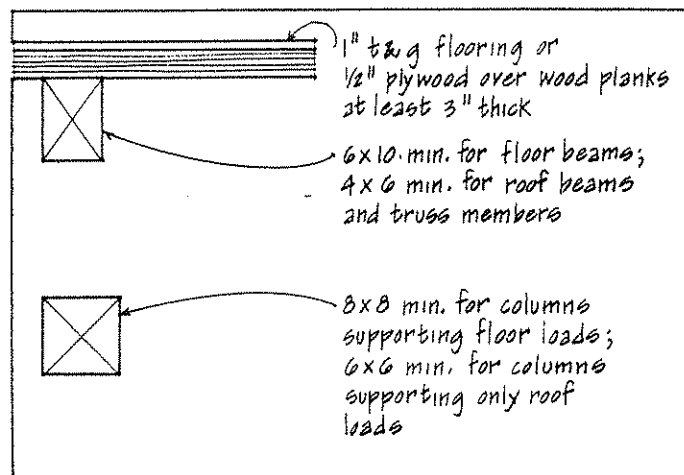
FLOOR AND ROOF PROTECTION

Materials used to provide fire protection for a building's elements must be inflammable and be able to withstand very high temperatures without disintegrating. They should also be low conductors of heat to insulate the protected materials from the heat generated by a fire.

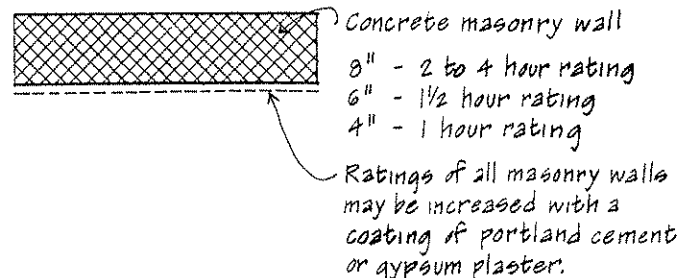
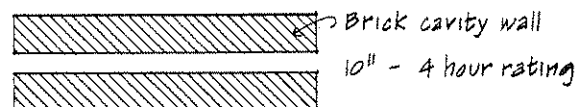
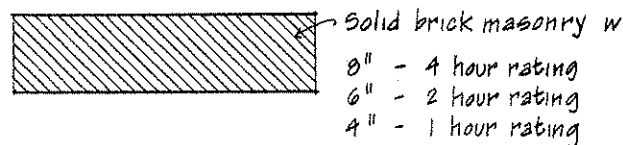
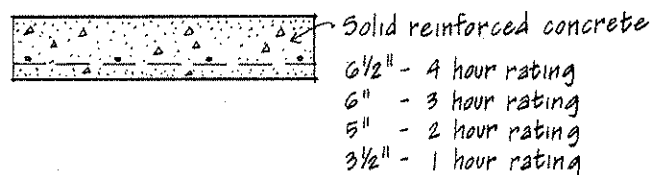
Materials commonly used for fire protection include concrete (often with lightweight aggregate), gypsum or vermiculite plaster, gypsum wallboard, and mineral fiber products. Wood may be chemically treated to reduce its flammability.



WALLS AND PARTITIONS

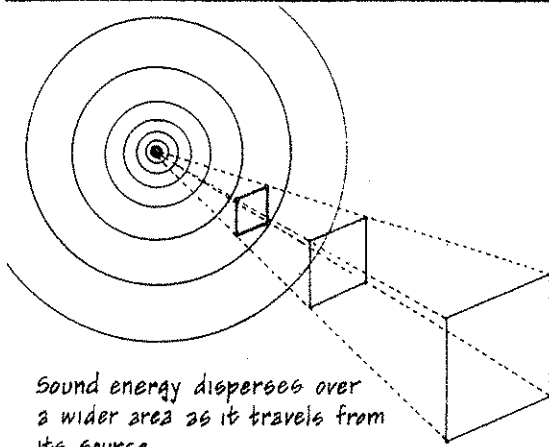


HEAVY TIMBER CONSTRUCTION



CONCRETE AND MASONRY WALLS

A.14 ACOUSTICS

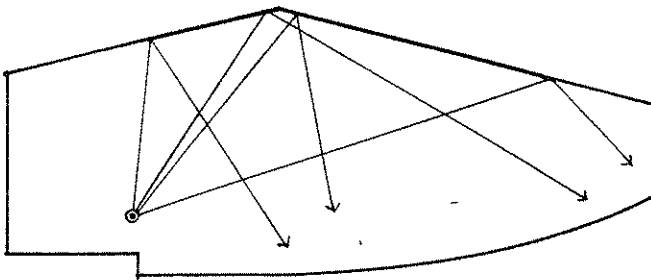
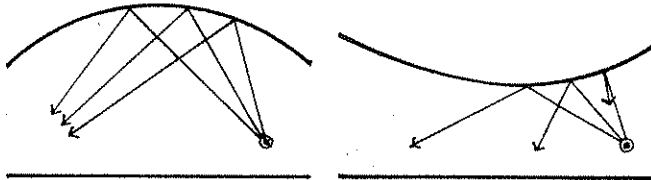
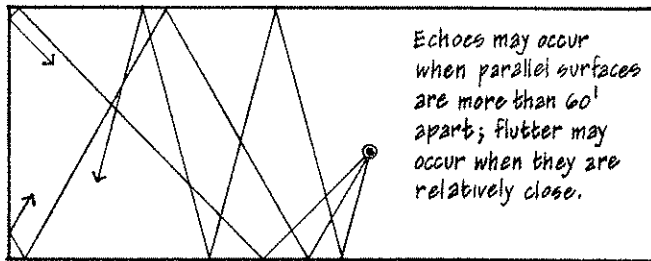


Acoustics may be defined as the science of sound, including its production and transmission, and the control of its effects. Sound requires a source for its production, a path for its transmission, and a receiver. It may be defined by the frequency, velocity, and magnitude of its energy waves. Sound waves generated by a vibrating object radiate outward from the source equally in all directions until they reach a surface that either reflects or absorbs them.

The acoustical design of spaces involves the reinforcement of desirable sounds and the control of undesirable noise. A room's acoustics is dependent on its shape, form, volume, and the nature of its surfaces.

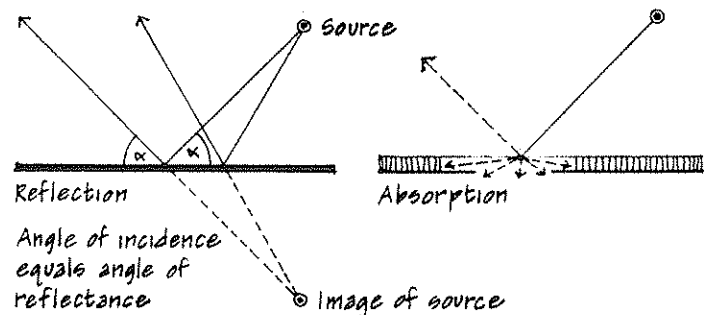
Room form

- Parallel surfaces reflect sound back and forth across a space.
- Parallel surfaces may cause excessive reverberation and undesirable echoes or flutter.
- Concave surfaces focus sound.
- Concave surfaces can create undesirable hot spots of sound.
- Convex surfaces diffuse sound.
- Diffused sound is desirable in listening areas.
- High cubical and long, narrowly proportioned spaces may require splayed surfaces to diffuse reflected sounds and absorbent surfaces to control reverberation.



Nature of the surfaces

- Hard surfaces reflect sound while soft, porous surfaces tend to absorb sound energy.
- The level of sound, reverberation time, and resonance desired for the intended use of a space will determine the area and disposition of hard and soft surfaces within the space.



SOUND CONTROL

Undesirable noise should be controlled at its source. Noise sources within a building include:

Mechanical equipment and supply systems

- Select quiet equipment.
- Use resilient mountings and flexible bellows to isolate equipment vibrations from the building structure and supply systems.
- Control noise transmission through ductwork by:
 - Lining the ducts internally with glass fiber
 - Installing sound attenuating mufflers
 - Using smooth duct turns.
- Minimize cross talk through ducts by maximizing the distance between diffusers in adjacent spaces.

Water supply and drainage systems

- Use expansion valves and flexible loop connections to prevent pipe rattling and noise transmission along the pipes.
- Seal pipe penetrations through walls and floors with flexible packing.

When control of a noise source does not reduce the undesirable sound to an acceptable level, then its transmission through the air or a building's structure must be controlled by sound absorption or isolation.

Sound absorption is achieved through the use of fibrous materials or panel resonators.

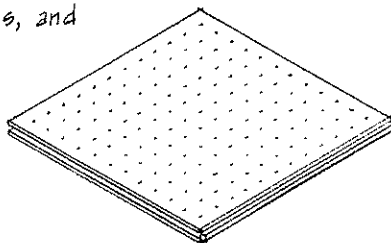
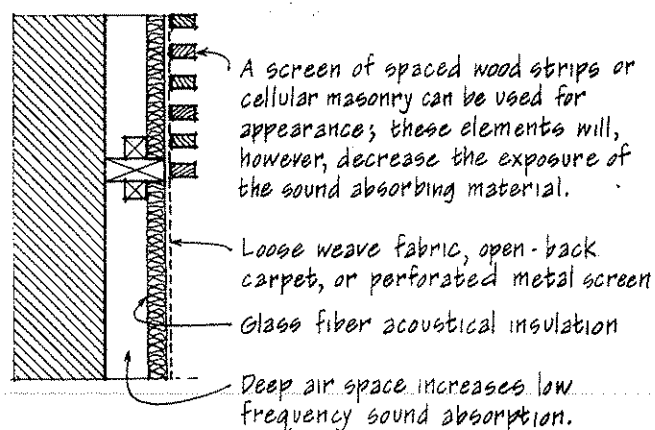
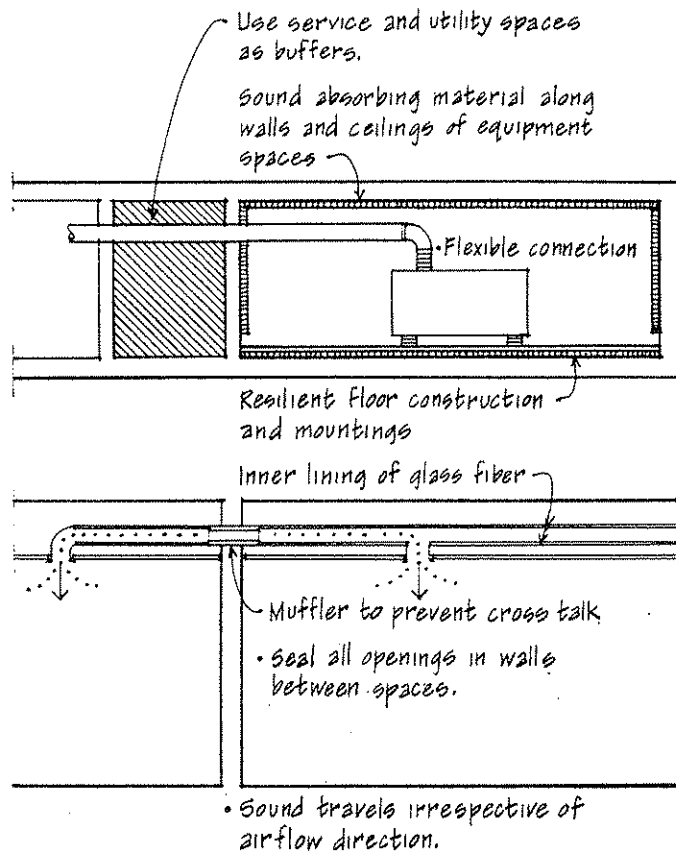
Fibrous materials

- The acoustic efficiency of a fibrous material depends on its thickness, density, porosity, exposure, and the method used to mount it.

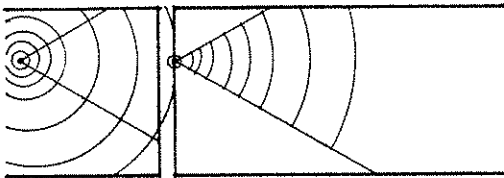
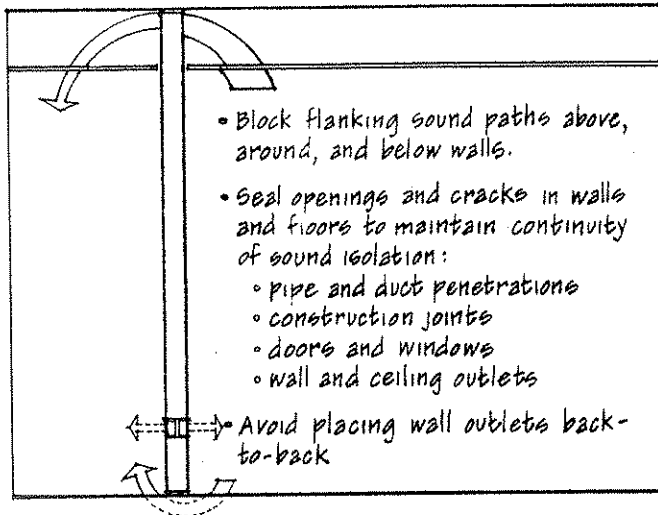
Panel resonators

- A panel resonator consists of a thin membrane material such as plywood mounted in front of a sealed air space. Panel resonators are effective absorbers of low frequency sounds.

Many sound-absorbing products are commercially available, such as acoustical ceiling tile. Other materials and products that are effective sound absorbers include carpeting, heavy drapes, and upholstered furnishings.

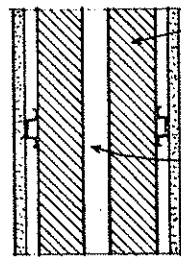


A.16 SOUND ISOLATION

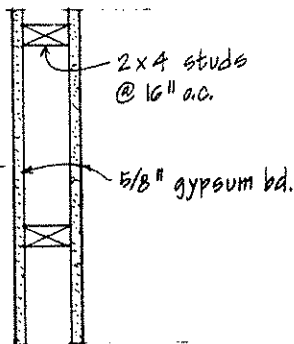


Sound isolation involves increasing a path's resistance to both air-borne and structure-borne sound.

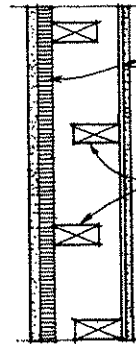
- The required reduction in noise level from one space to another depends on the level of the sound source and the level of the sound's intrusion that may be acceptable to the listener.
- The perceived or apparent sound level in a space is dependent on:
 - the transmission loss through the wall, floor, and ceiling construction
 - the absorptive qualities of the receiving space
 - the level of background or masking sound, which increases the threshold of audibility for other sounds in its presence.
- A wall or floor construction that is vibrated by the energy waves from a sound source will itself become a sound source.
- The transmission loss through a wall or floor construction depends on the frequency of the sound and the construction's mass, resilience, and area.



- Sound transmission loss through a material increases in proportion to its mass.
- Air spaces increase transmission loss



STC = 30 to 34



STC = 50 to 54

- STC (Sound transmission class) is an index of a partition's resistance to the passage of sound.

The Construction Specifications Institute (CSI) has established Masterformat, a standard outline for construction specifications. This format is also used to organize the technical literature published by trade associations and manufacturers.

Masterformat has sixteen primary divisions.

Division 1 • General Requirements

Division 2 • Sitework

Division 3 • Concrete

Division 4 • Masonry

Division 5 • Metals

Division 6 • Wood and Plastics

Division 7 • Thermal and Moisture Protection

Division 8 • Doors and Windows

Division 9 • Finishes

Division 10 • Specialties

Division 11 • Equipment

Division 12 • Furnishings

Division 13 • Special construction

Division 14 • Conveying systems

Division 15 • Mechanical

Division 16 • Electrical

Each division is subdivided into specific categories, each of which is assigned a five-digit number. To the right and on the following pages, major subdivisions are listed. For a complete list, write to the Construction Specifications Institute.

DIVISION 1 • GENERAL REQUIREMENTS

01010 Summary of work
01020 Allowances
01025 Measurement and payment
01030 Alternates/alternatives
01035 Modification procedures
01040 Coordination
01050 Field engineering
01060 Regulatory requirements
01070 Identification systems
01090 References
01100 Special project procedures
01200 Project meetings
01300 Submittals
01400 Quality control
01500 Construction facilities
01600 Material and equipment
01650 Facility startup/commissioning
01700 Contract closeout
01800 Maintenance

DIVISION 2 • SITEWORK

02010 Subsurface investigation
02050 Demolition
02100 Site preparation
02140 Dewatering
02150 Shoring and underpinning
02160 Excavation support systems
02170 Cofferdams
02200 Earthwork
02300 Tunneling
02350 Piles and caissons
02480 Marine work
02500 Paving and surfacing
02600 Utility piping materials
02660 Water distribution
02680 Fuel and steam distribution
02700 Sewerage and drainage
02760 Restoration of underground pipe
02770 Ponds and reservoirs
02780 Power and communications
02800 Site improvements
02900 Landscaping

A.18**CSI MASTERFORMAT (Continued)****DIVISION 3 • CONCRETE**

- 03100 Concrete formwork
- 03200 Concrete reinforcement
- 03250 Concrete accessories
- 03300 Cast-in-place concrete
- 03370 Concrete curing
- 03400 Precast concrete
- 03500 Cementitious decks and toppings
- 03600 Grout
- 03700 Concrete restoration and cleaning
- 03800 Mass concrete

DIVISION 4 • MASONRY

- 04100 Mortar and masonry grout
- 04150 Masonry accessories
- 04200 Unit masonry
- 04400 Stone
- 04500 Masonry restoration and cleaning
- 04600 Corrosion resistant masonry
- 04700 Simulated masonry

DIVISION 5 • METALS

- 05010 Metal materials
- 05030 Metal coatings
- 05050 Metal fastenings
- 05100 Structural metal framing
- 05200 Metal joists
- 05300 Metal decking
- 05400 Cold formed metal framing
- 05500 Metal fabrications
- 05580 Sheet metal fabrications
- 05700 Ornamental
- 05800 Expansion control
- 05900 Hydraulic structures

DIVISION 6 • WOOD AND PLASTICS

- 06050 Fasteners and adhesives
- 06100 Rough carpentry
- 06130 Heavy timber construction
- 06150 Wood and metal systems
- 06170 Prefabricated structural wood
- 06200 Finish carpentry
- 06300 Wood treatment
- 06400 Architectural woodwork
- 06500 Structural plastics
- 06600 Plastic fabrications
- 06650 Solid polymer fabrications

DIVISION 7 • THERMAL AND MOISTURE PROTECTION

- 07100 Waterproofing
- 07150 Dampproofing
- 07180 Water repellants
- 07190 Vapor retarders
- 07195 Air barriers
- 07200 Insulation
- 07240 Exterior insulation and finish systems
- 07250 Fireproofing
- 07270 Firestopping
- 07300 Shingles and roofing tiles
- 07400 Manufactured roofing and siding
- 07480 Exterior wall assemblies
- 07500 Membrane roofing
- 07600 Flashing and sheet metal
- 07700 Roof specialties and accessories
- 07800 Skylights
- 07900 Joint sealers

DIVISION 8 • DOORS AND WINDOWS

- 08100 Metal doors and frames
- 08200 Wood and plastic doors
- 08250 Door opening assemblies
- 08300 Special doors
- 08400 Entrances and storefronts
- 08500 Metal windows
- 08600 Wood and plastic windows
- 08650 Special windows
- 08700 Hardware
- 08800 Glazing
- 08900 Glazed curtain walls

DIVISION 9 • FINISHES

- 09100 Metal support systems
- 09200 Lath and plaster
- 09250 Gypsum board
- 09300 Tile
- 09400 Terrazzo
- 09450 Stone facing
- 09500 Acoustical treatment
- 09540 Special wall surfaces
- 09545 Special ceiling surfaces
- 09550 Wood flooring
- 09600 Stone flooring
- 09630 Unit masonry flooring
- 09650 Resilient flooring
- 09680 Carpet
- 09700 Special flooring
- 09780 Floor treatment
- 09800 Special coatings
- 09900 Painting
- 09950 Wall coverings

DIVISION 10 • SPECIALTIES

10100	Visual display boards
10150	Compartments and cubicles
10200	Louvers and vents
10270	Access flooring
10300	Fireplaces and stoves
10350	Flagpoles
10400	Identifying devices
10500	Lockers
10520	Fire protection specialties
10600	Partitions
10650	Operable partitions
10670	Storage shelving
10700	Exterior protection devices for openings
10750	Telephone specialties
10800	Toilet and bath accessories

DIVISION 11 • EQUIPMENT

11010	Maintenance equipment
11020	Security and vault equipment
11040	Ecclesiastical equipment
11050	Library equipment
11060	Theater and stage equipment
11100	Mercantile equipment
11130	Audio-visual equipment
11150	Parking control equipment
11160	Loading dock equipment
11170	Solid waste handling equipment
11190	Detention equipment
11200	Water supply and treatment equipment
11300	Fluid waste treatment and disposal
11400	Food service equipment
11450	Residential equipment
11460	Unit kitchens
11470	Darkroom equipment
11480	Athletic and recreational equipment
11600	Laboratory equipment
11680	Office equipment
11700	Medical equipment
11870	Agricultural equipment

DIVISION 12 • FURNISHINGS

12050	Fabrics
12100	Artwork
12300	Manufactured casework
12500	Window treatment
12600	Furniture and accessories
12670	Rugs and mats
12700	Multiple seating
12800	Interior plants and planters

DIVISION 13 • SPECIAL CONSTRUCTION

13010	Air supported structures
13020	Integrated assemblies
13030	Special purpose rooms
13080	Sound, vibration, and seismic control
13090	Radiation protection
13120	Pre-engineered structures
13150	Aquatic facilities
13300	Utility control systems
13500	Recording instrumentation
13600	Solar energy systems
13700	Wind energy systems
13750	Cogeneration systems
13800	Building automation systems
13900	Fire suppression systems
13950	Special security construction

DIVISION 14 • CONVEYING SYSTEMS

14100	Dumbwaiters
14200	Elevators
14300	Escalators and moving walks
14400	Lifts
14500	Material handling systems
14600	Hoists and cranes
14800	Scaffolding
14900	Transportation systems

DIVISION 15 • MECHANICAL

15050	Mechanical materials and methods
15250	Mechanical insulation
15300	Fire protection
15400	Plumbing
15500	Heating, ventilating, and air conditioning
15550	Heat generation
15650	Refrigeration
15750	Heat transfer
15850	Air handling
15880	Air distribution
15950	Controls
15990	Testing, adjusting, and balancing

DIVISION 16 • ELECTRICAL

16050	Electrical materials and methods
16200	Power generation systems
16300	Medium voltage distribution
16400	Service and distribution
16500	Lighting
16600	Special systems
16700	Communications
16850	Electric resistance heating
16900	Controls
16950	Testing

A.20 TRADE ASSOCIATIONS

Trade associations are valuable sources of product information and construction standards.

- Adhesives Manufacturers Association • 111 E. Wacker Dr., Chicago, IL 60601
- Air-Conditioning and Refrigeration Institute • 1501 Wilson Blvd., Arlington, VA 22209
- Aluminum Association • 900 19th St. NW, Suite 300, Washington, DC 20006
- American Architectural Manufacturers Association • 2700 River Rd., Suite 118, Des Plaines, IL 60018
- American Concrete Institute • P.O. Box 19150, Redford Station, Detroit, MI 48219
- American Concrete Pipe Association • 8320 Old Courthouse Rd., Vienna, VA 22180
- American Forest Council • 1250 Connecticut Ave. NW, Washington, DC 20006
- American Gas Association • 1515 Wilson Blvd., Arlington, VA 22209
- American Hardboard Association • 520 N. Hicks Rd., Palatine, IL 60067
- American Hardware Manufacturers Association • 931 N. Plum Grove Rd., Schaumburg, IL 60173
- American Home Lighting Institute • 230 N. Michigan Ave., Chicago, IL 60601
- American Institute of Architects • 1735 New York Ave. NW, Washington, DC 20006
- American Institute of Steel Construction, Inc. • 400 N. Michigan Ave., Chicago, IL 60611
- American Institute of Timber Construction • 11818 E. Mill Plain Blvd., Vancouver, WA 98684
- American Insurance Association • 85 John St., New York, NY 10038
- American National Standards Institute, Inc. • 1430 Broadway, New York, NY 10018
- American Paper Institute • 260 Madison Ave., New York, NY 10016
- American Plywood Association • 7011 S. 10th St., Tacoma, WA 98411
- American Society for Testing and Materials • 1916 Race St., Philadelphia, PA 19103
- American Society of Civil Engineers • 345 E. 47th St., New York, NY 10017
- American Society of Heating, Refrigeration, and Air-Conditioning Engineers • 1791 Tullie Circle NE, Atlanta, GA 30329
- American Society of Landscape Architects • 4401 Connecticut Ave. NW, Washington, DC 20006
- American Society of Mechanical Engineers • 345 E. 47th St., New York, NY 10017
- American Society of Sanitary Engineering • P.O. Box 40362, Bay Village, OH 44140
- American Wood Preservers Institute • 1945 Galois Rd., Vienna, VA 22180
- Architectural Woodwork Institute • 2310 S. Walter Reed Dr., Arlington, VA 22206
- Asphalt Roofing Manufacturers Association • 6288 Montrose Rd., Rockville, MD 20852
- Associated General Contractors of America, Inc. • 1957 E St. NW, Washington, DC 20006
- Battelle Memorial Institute • 505 King Ave., Columbus, OH 43201
- Brick Institute of America • 11490 Commerce Park Dr., Reston, VA 22091
- Building Officials and Code Administrators International Inc. • 4051 Flossmoor Rd., Country Club Hills, IL 60477
- Building Research Advisory Board • 2101 Constitution Ave., Washington, DC 20418
- California Redwood Association • 405 Enfrente Dr., Novato, CA 94940
- Carpet and Rug Institute • 310 Holiday Dr., Dalton, GA 30720
- Cast Iron Soil Pipe Institute • 5950 Shallowford Rd., Chattanooga, TN 37421
- Cedar Shake and Shingle Bureau • 515 116th Ave. NE, Bellevue, WA 98004
- Concrete Reinforcing Steel Institute • 933 N. Plum Grove Rd., Schaumburg, IL 60173
- Construction Specifications Institute • 601 Madison St., Alexandria, VA 22314
- Copper Development Association, Inc. • 405 Lexington Ave., New York, NY 10017
- Council of American Building Officials • 2233 Wisconsin Ave. NW, Washington, DC 20007
- Door and Hardware Institute • 7711 Old Springhouse Rd., McLean, VA 22102
- Ductile Iron Pipe Research Association • 245 Riverchase Parkway E., Birmingham, AL 35244
- Electrification Council • 1111 19th St. NW, Washington, DC 20036
- Expanded Shale, Clay and Slate Institute • 6218 Montrose Rd., Rockville, MD 20852
- Facing Tile Institute • Box 8880, Canton, OH 44711
- Fine Hardwoods- American Walnut Association • 5603 W. Raymond St., Indianapolis, IN 46241
- Flat Glass Marketing Association • 3310 Harrison, Topeka, KS 66611
- Forest Products Laboratory • U.S. Dept. of Agriculture, P.O. Box 5130, Madison, WI 53705
- Gypsum Association • 1603 Orrington Ave., Evanston, IL 60201
- Hardwood Manufacturers Association • 2831 Airways Blvd., Memphis, TN 38132
- Hardwood Plywood Manufacturers Association • 1825 Michael Faraday Dr., Reston, VA 22090
- Home Ventilating Institute • 30 W. University Dr., Arlington Hts., IL 60004
- IIT Research Institute • 10 W. 35th St., Chicago, IL 60616

Illuminating Engineering Society of North America • 345 E. 47th St., New York, NY 10017
 Indiana Limestone Institute of America, Inc. • Suite 400, Stone City Bank Bldg., Bedford, IN 47421
 International Conference of Building Officials • 5360 S. Workman Mill Rd., Whittier, CA 90601
 Maple Flooring Manufacturers Association • 60 Revere Dr., Northbrook, IL 60062
 Marble Institute of America • 33505 State St., Farmington, MI 48024
 Metal Lath/Steel Framing Association • 600 S. Federal St., Chicago, IL 60605
 Mineral Insulation Manufacturers Association • 1420 King St., Alexandria, VA 22314
 NAHB Research Foundation, Inc. • P.O. Box 1627, Rockville, MD 20850
 National Bureau of Standards • Center for Building Technology, Washington, DC 20234
 National Concrete Masonry Association • 2302 Horse Pen Rd., Herndon, VA 22070
 National Electrical Manufacturers Association • 2101 L St. NW, Washington, DC 20037
 National Fire Protection Association • 1800 M St. NW, Washington, DC 20036
 National Forest Products Association • 1250 Connecticut Ave. NW, Washington, DC 20006
 National Hardwood Lumber Association • P.O. Box 34518, Memphis, TN 38184
 National Kitchen Cabinet Association • P.O. Box 6830, Falls Church, VA 22046
 National Oak Flooring Manufacturers Association • P.O. Box 3009, Memphis, TN 38173
 National Paint and Coatings Association • 1500 Rhode Island Ave. NW, Washington, DC 20005
 National Particleboard Association • 18925 Premiere Ct., Gaithersburg, MD 20879
 National Precast Concrete Association • 825 E. 64th St., Indianapolis, IN 46220
 National Research Council of Canada • Ottawa, Canada, KIA 0R6
 National Safety Council • 444 N. Michigan Ave., Chicago, IL 60611
 National Society of Professional Engineers • 1420 King St., Alexandria, VA 22314
 National Terrazzo and Mosaic Association • 3166 Des Plaines Ave., Des Plaines, IL 60018
 National Wood Window and Door Association • 1400 E. Touhy Ave., Des Plaines, IL 60018
 Northeastern Lumber Manufacturers Association • 4 Fundy Rd., Falmouth, ME 04105
 Perlite Institute, Inc. • 600 S. Federal St., Chicago, IL 60605
 Plastic Pipe Institute • 355 Lexington Ave., New York, NY 10017
 Plywood Research Foundation • P.O. Box 11700, Tacoma, WA 98411
 Porcelain Enamel Institute • 1101 Connecticut Ave. NW, Washington, DC 20036
 Portland Cement Association • 5420 Old Orchard Rd., Skokie, IL 60076
 Resilient Floor Covering Institute • 966 Hungerford Dr., Rockville, MD 20805
 Society of American Registered Architects • 1245 S. Highland Ave., Lombard, IL 60148
 Society of American Wood Preservers, Inc. • 7297 Lee Hwy., Falls Church, VA 22042
 Society of Plastics Industries, Inc. • 1275 K St. NW, Washington, DC 20005
 Southern Building Code Congress International • 900 Montclair Rd., Birmingham, AL 35213
 Southern Cypress Manufacturers Association • 2931 Airways Blvd., Memphis, TN 38132
 Southern Forest Products Association • P.O. Box 52468, New Orleans, LA 70152
 Stanford Research Institute • 333 Ravenswood Ave., Menlo Park, CA 94025
 Steel Deck Institute • P.O. Box 3812, St. Louis, MO 63122
 Steel Door Institute • 14600 Detroit Ave., Cleveland, OH 44107
 Steel Joist Institute • 1205 48th Ave. N., Myrtle Beach, SC 29577
 Steel Manufacturers Association • 815 Connecticut Ave. NW, Washington, DC 20006
 Steel Window Institute • 1230 Keith Bldg., Cleveland, OH 44115
 Stucco Manufacturers Association • 14006 Ventura Blvd., Sherman Oaks, CA 91423
 Superintendent of Documents • U.S. Government Printing Office, Washington, DC 20402
 Tile Council of America • P.O. Box 326, Princeton, NJ 08542
 Underwriters' Laboratories, Inc. • 333 Pfingsten Rd., Northbrook, IL 60062
 Urban Land Institute • 1090 Vermont Ave. NW, Washington, DC 20005
 U.S. Dept. of Housing and Urban Development • 451 Seventh St. SW, Washington, DC 20411
 U.S. League of Savings Institutions • 1709 New York Ave. NW, Washington, DC 20006
 Vermiculite Association • 600 S. Federal St., Chicago, IL 60605
 Western Red Cedar Lumber Association • 1500 Yeon Bldg., Portland, OR 97204
 Western Wood Products Association • 1500 Yeon Bldg., Portland, OR 97204
 Wire Reinforcement Institute • 8316-A Greensboro Dr., McLean, VA 22102

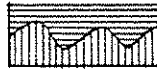
A.22 GRAPHIC MATERIAL SYMBOLS

These symbols are some of the abstract conventions commonly used in architectural drawings.

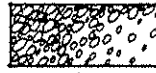
EARTH



Earth



Rock



Gravel

CONCRETE



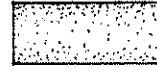
Structural



Lightweight

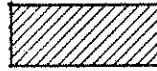


Block



Plaster, mortar, sand

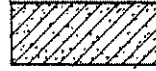
BRICK



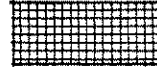
Common, facing



Fire brick

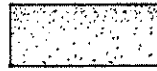


Adobe



Structural facing tile

STONE



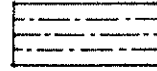
Cut stone



Rubble



Marble



Slate



Cast stone

METAL



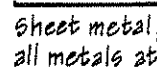
Iron, steel



Aluminum



Brass, bronze



Sheet metal,
all metals at
small scale

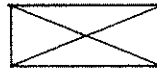


Structural

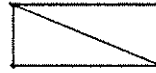
WOOD



Finish



Rough



Blocking

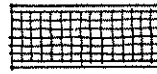


Plywood (large scale & small scale)

INSULATION



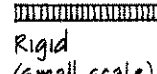
Batt, loose fill



Rigid

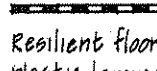


Spray, foam

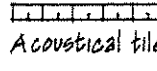


Rigid
(small scale)

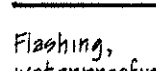
OTHER



Resilient flooring,
plastic laminate



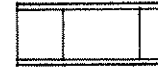
Acoustical tile



Flashing,
waterproofing



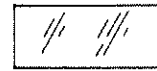
Glass
(large & small
scales)



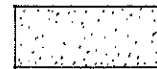
Glass block

• PLAN AND SECTION INDICATIONS

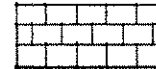
GLAZING



CONCRETE & PLASTER



STONE

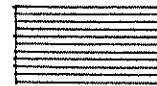


Ashlar

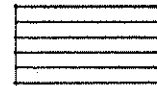


Rubble

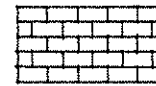
MASONRY



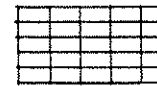
Brick



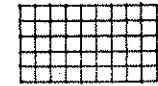
Conc. block



Running bond



Stack bond



Ceramic tile

WOOD



Shingles



Panel

METAL



• Within the limitations of a drawing's scale, a material's texture and pattern should be indicated as accurately as possible.

• ELEVATION INDICATIONS